

Admixture-elements and their use as geochemical indicators for search of buried pyrite ores in the Greater Caucasus (Azerbaijan)

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Abstract

Heterogeneous pyritaceous-polymetallic and copper-zinc-pyrrhotine deposits on the South slope of the Greater Caucasus are located in the Lower-Middle Jurassic terrigenous sediments. They were formed under a wide variation of physico-chemical parameters of mineral formation and are characterized by specific mineralogical-geochemical peculiarities. Ore-formation occurred in three stages. In the first stage, massive hydrothermal-sedimentary sulphurous-pyrite ores were deposited. The formation of the second stage of hydrothermal-metasomatic pyrite-polymetallic ores was prior to the intrusion of constant differentiated formation dikes. In the third stage hydrothermal-metamorphogenic copper-pyrrhotine ores were formed. Stratiform pyrite deposits can be characterized by a large variety of textural-mineralogical types of ores and mineral associations, by rich mineral composition and a rather wide geochemical spectrum. As a whole, among the studied admixture-elements (Tl, Ag, Hg as well as B, Li, Rb) one can find accumulating tendency in the above-ore series, near ores with pyrite-polymetallic composition. Other group of elements (Co, Sn, Mn, Mo and Bi) shows accumulation in the under-ore series. Deeper horizons of sandy-clayey rocks are enriched in uranium and potassium while the higher horizons are enriched in thorium above the ore deposit. Distribution peculiarities of such components (Tl, Ag, Hg, Sn and also Mo, Bi, K, U, Th) in the host the rocks of pyrite deposits of Greater Caucasus of South slope allows one to consider them along with ore forming components (Zn, Pb, Cu) as indicator elements for search of buried ore accumulations in the Lower-Middle Jurassic sandy-clayey deposits of region.

Keywords: Admixture-elements, Pyrite-polymetallic, Host rock, Geochemical indicator.

1. Introduction

Stratiform pyrite deposits of the Greater Caucasus Eastern segment located in the Lower-Middle Jurassic sandy-clay deposits can be characterized by a large variety of textural-mineralogical types of ores and mineral associations, by rich mineral composition and a rather wide geochemical spectrum. Here belong the following deposits: Filizchai, Katekh, Katsdag, Jikhikh-Sagator in the Azerbaijan area of the Greater Caucasus South slope, Kizil-Dere deposit in South Dagestan and numerous ore indices. These studied ore deposits are called Filizchai-type and combine the properties of Ural, Cyprus, Kuroko and Besshi types. Their common features with the first two types is a high amount of iron and increased concentration of some siderophile elements (Co, Ni, Mn) in pyrite, and with ores of a Kuroko type - the proximity of correlation of main components (Zn, Pb, Cu) and the amounts of chalcophile admixing components (Sb, As, Bi, Sn) in pyrite and in the ores on the whole; by high concentration in the latter of sulfosalts of Ag, Pb, Cu and Bi.

Their common features with ores of Besshi type is the similarity of the main minerals and the levels of concentration of noble metals (Au, Ag) in the ores. The stratiform Filizchai deposit is the largest pyrite-polymetallic deposit in the Caucasus ore deposit which is more complex due to the combination of various natural ore types. Textural-mineralogical natural ore types within the whole bed take a systematic position: the more widespread stratified-banded pyrite-polymetallic ores (more than 70 % of the deposit volume) are localized mainly in the hanging wall; massive pyrite-polymetallic and sulfur pyrite ores can be found jointly with stratified-banded ones mainly in the deep horizons of the north-eastern part of deposit; spotted-breccia-like sulfur pyrite and pyrite-polymetallic ores and copper-pyrrhotine ores with massive texture are developed exceptionally in the eastern part of the deposit at the side of the deposit base where the vein-impregnated ores alternate both in the dip and in the strike direction.

The structure of the top and the base of bed-like deposit is characterized by some peculiarities. The top of the deposit is more stable on all its extensions. The base of the deposit is characterized by a complex structure including sharp contacts with the host rocks. On the other hand, a great variety of natural ore types

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is confined to the base which cannot be found in the top. Intensive hydrothermal-metasomatic rocks changes (carbonatization, silicification, chloritization, sericitization) can be found in the sub-ore series.

The ores in the Filizchai deposit possess a rich mineral composition. Pyrite is the dominant sulfide mineral accompanied by sphalerite, galenite, chalcopyrite and pyrrhotine.] The secondary and rare minerals are as follows: marcasite, arsenopyrite, cobaltine, linnaeite, magnetite, tennantite, tetrahedrite, different sulfosalts of copper and lead, bismuth minerals, tellurides of gold and silver. Hypergene minerals are: iron hydroxides, malachite, azurite, chalcocite, covellite, tenorite, chalcantite, cerussite, anglesite, jarosite, gossarite, scorodite etc. Non-ore minerals are represented by quartz, carbonates, chlorite, sericite, etc.

Ore-formation occurred in three stages in the studied area. In the first stage massive hydrothermal-sedimentary sulphurous-pyrite ores were deposited. The formation of the second stage of hydrothermal-metasomatic pyrite-polymetallic ores was earlier than the intrusion of constant differentiated formation dikes. In the third stage hydrothermal-metamorphogenic copper-pyrrhotine ores were formed. Ore deposition occurred below a temperature of 150°C in the first stage [1]. The study of temperature in pyrite deposits ores formation by homogenization of gas-fluid intrusion by A.G. Tvalchrelidze [2], provided the following results: pyrite-polymetallic ores on average 120°C (Filizchai deposit) and 145°C (Katsdag deposit); copper-pyrrhotine –on average 300°C. The same temperature for copper-pyrrhotine ores was defined by us through pyrite-pyrrhotine and chalcopyrite-pyrrhotine geothermometers [3, 4]. On the basis of isotopic thermometry of the basic ore-forming sulphides, N.M. Zairi et al. [5] defined the temperature of sulphide ore crystallization in Katekh, Filizchai and Katsdag deposits. It has been determined that the later copper-pyrrhotine stage of mineral formation can be characterized by high temperature (on average 440°C in Filizchai and 410°C in Katsdag) in comparison with earlier pyrite-polymetallic stage (pyrite stage on average 310°C and polymetallic on average 240°C). Similar data is available in other authors' works.

Manifestation of polysulphide mixtures is specific for pyrite-polymetallic ores of Katekh deposit. It is represented by tight germination of small isolations of galenite, sphalerite, chalcopyrite and pyrite. The amount of pyrrhotine significantly increases in the ores of Katsdag, Jikhikh-Sagator and Kizil-Dere.

Using the cadmium geothermometer for the sphalerite-galenite pair [6], we can calculate the temperature criterion for the formation of pyrite-polymetallic ores deposits in the region within 243^o-280^oC and this agrees with the results of other researchers. Mineralization occurred in conditions of

changing acid-alkalinity in solutions by alternating values of redox regime.

2. Results and Discussion

2-1 Rare and noble metals in ores

It is known that ores of pyritaceous deposits are a very important source of some rare and noble metals. The investigated pyritaceous deposits on the South slope of the Great Caucasus are characterized by a wide range of admixture components. Together with common features in the distribution of main and attendant components, in textural-mineralogical types of ores and main sulfide minerals, one can notice certain specific features for every deposit. For the majority of elements-admixtures despite some differences between the mineral-carriers, the concentrators in all the studied deposits are almost one and the same viz. sulfide minerals. Among the rare elements of special attention is a group of elements with a common dispersed distribution (and nearly complete absence of even the slightest commercial concentrations) which have a tendency to accumulate in the endogenic ore deposits. In the geochemical literature these components (Cd, In, Tl, Ga, Ge, Bi, Se, Te, Re) compose a group of chalcophile rare elements.

Cadmium is a constant admixture of sphalerite (maximum up to 0.5%) of the investigated ores. Its concentration grows during mineral formation from marmatite to cleiophane. In other sulfides its amount is 10² times lower.

Increased concentrations of **Indium** are linked with sulfides possessing the quadruple coordination (sphalerite, chalcopyrite) and for minerals with the sextuple coordination (pyrite, pyrrhotine, galenite) low concentrations of the element are typical. In the dark-coloured varieties of sphalerite the amount of indium is nearly two times higher than in the light-coloured variety (95ppm and 55ppm respectively). Existence of two varieties of the mineral is indicated by a bimodal character of the histogram of frequency of indium distribution in sphalerite from Filizchai and Katsdag deposits. Our investigations also demonstrated the absence of a clear linkage between the change of amount of indium in sphalerite and its iron content in the pyritaceous deposits in the region.

In the investigated ores **Thallium** tends to accumulate, on the one hand, in lead minerals (galenite and bournonite) and on the other hand, in colomorph pyrite. In the lead sulfide thallium exists isomorphically according to the scheme:

$2 \text{Pb}^{2+} \leftarrow \text{Tl}^{1+} + \text{Sb}^{3+} (\text{Bi}^{3+})$, and in pyrite- as a sorption. Pyrite of endogenous origin contains ten times higher thallium than in pyrites of sedimentary origin. The maximum amount of the element was determined in massive thin-grained pyrite-polymetallic ore in the Katekh deposit – 0.056 % [7].

Gallium is not a typical admixture of the investigated ores. Its amount is different in vein-impregnated ores (on average 19ppm). This is due to the gallium content of the sandy-clayey host as a result of accumulation of the element in the silicate component. The highest amount of the element (up to 40 ppm) was determined in the light sphalerite.

The amount of **Germanium** is low. Decreased background of germanium content of these pyritaceous deposits is probably linked with the initial impoverishment of the ore-forming solutions in this element. It is quite obvious that the silicate structure played an important role in the distribution of the element as well, a small amount of which was dispersed in the enclosing deposits due to crystal-chemical proximity of Ge^{4+} and Si^{4+} .

Selenium and Tellurium are among the admixture components of ores occurring everywhere. Galenite together with pyrite and pyrrhotine are mineral-concentrators of selenium. A certain role is played by chalcopyrite. The Katekh pyritaceous-polymetallic field is famous for the selenium content of galenites in the region where the highest amount of the element is up to 360ppm (on an average 205ppm). Concentration of tellurium in the mineral (average 96ppm) is of a certain importance too. Unlike selenium, besides its isomorphic existence in the sulfides, it is individualized in numerous proper minerals. Among copper-pyrrhotine mineral association of pyritaceous deposits in the region, chalcopyrite is the only leading sulfide mineral where tellurium prevails over selenium. In the distribution of selenium in varieties of pyrite it was determined that increased concentrations of the element are present in the crystalline variety of the mineral. Thus, there exists dependence between the amount of selenium and crystal maturity of pyrite.

Bismuth is a constant companion of the investigated ores. Its mineral-concentrator is galenite (Table 1). Due to the high amount of galenite as well as the widespread occurrence of bismuth minerals (bismutite, tellurobismutite, tetradyrite, emplectite, beegerite, cosalite etc.) in the bedded-foliated and the massive pyritaceous-polymetallic ores in the Filizchai deposit, exactly these textural-mineralogical types of ore have the highest bismuth content.

Gold and Silver are typomorphic admixtures of pyritaceous ores in the region. The main amount of both elements is linked with the productive pyritaceous-polymetallic ore-formation. The maximum concentration of gold in some samples of pyritaceous-polymetallic ores is 3.6ppm, while that of silver is 380ppm. Pyrite and chalcopyrite are mineral-concentrators of gold, and galenite of silver. A certain role is played by secondary minerals - arsenopyrite and tetrahedrite (according to their distribution). Usually they contain the highest concentrations of gold and silver as evidenced by significant correlations in pairs of elements Au-As and Ag-Sb in the ores. Existence of

proper minerals of noble metals in the investigated ores is of importance as well (petzite, hessite, nagyagite, argentite, freibergite, dyscrasite, benjaminite, volynskite, native gold and silver). Values of silver-gold relation are higher in the Filizchai type as related to the Cyprusian, Ural, Kuroko and Besshi types of pyritaceous deposits [8, 9]. The presence of Cobalt in these ores is of great importance. In the Filizchai deposit this element is present in equal amounts (average 200ppm) in the bedded-foliated and the massive pyrite-polymetallic ores. In the massive sulphurous-pyrite ores the cobalt content increases by a factor of two. In the copper-pyrrhotine ores the cobalt concentration is a bit lesser than in the sulphurous pyrite ores. A systematic cobalt increase can be found from earlier to late generations of pyrrhotine. The maximum cobalt concentration is confined to pyrite III, which contains the basic part of pyrite-polymetallic ores. Usually the cobalt concentration prevails over nickel in the studied sulphide minerals. The same situation can be found in industrial ore types where the ratios of average cobalt to nickel contents vary from 1.8 to 3.2. The contents of these elements are nearly equal in vein-impregnated ores or a little more nickel is present due to its geochemical behaviour.

2-2. Distribution in host rocks

The wallrock of the sandy-clayey pyrite deposits of the Greater Caucasus South slope was subjected to different metasomatic transformations such as silicification, carbonatization, sericitization and chloritization and one can find the following: there are the same chemical elements which are typical for the ore mass, i.e. one geochemical spectrum exists. However, these elements are less by many times than in the ores, excepting gallium, germanium and nickel (Fig. 1). Multicomponent ore deposits of pyrite-polymetallic deposits in the region are accompanied by polyelement geochemical aureoles. Hydrothermal-metasomatic transformations spatially and genetically connected with the mineralization are mainly found on the footwall side of deposits. Here systematic spatial distribution of metasomatites can be observed by approaching them. Geochemical peculiarities of the components distribution in host rocks of pyrite deposits were studied in many works where the study focused mainly on the ore forming components (Cu, Zn, and Pb). In our research conducted along with the basic elements great attention was also paid to the distribution peculiarities of ore admixture-elements and also alkaline and radioactive elements in the lithological facies of the sandy-clay rocks. It has been established that the clayey composition of rocks has a positive effect on the concentration of some admixture-elements: Tl, Ag, Co, Mn, Sn, Hg, B, Li, Th, and U (Table 2). This is due on the one hand – to their considerable sorption volume and on the other hand – due to the negative charge of their colloids.

Concentration levels of many components depend upon the extent of near-ore variation of rocks, their location in the vertical metal bearing column relative to the ore deposit, upon the proximity and the mineral composition of the ore in contact. A clear mineralogical-geochemical zonation of a deposit is defined in the pyrite deposits of the region, first in the Filizchai deposit. It is expressed by systematic location of some textural mineralogical ore types (bedded-foliated and massive pyrite-polymetallic, massive sulfur-pyrite and copper-pyrrhotine, spotted-breccia-like) and appropriate changes of concentration levels and a number of other geochemical indicators of ore forming and admixture components on the depth, thickness and strike length [7,10] in space. It is reflected also in the structure of geochemical zonation of studied admixture components in the ore containing series; in their location in the above-ore and under-ore series where the aureole forming admixture-elements are prevalent. So, one can see general patterns (concentration increase of zinc, lead, silver, thallium, mercury and so on in the upper part of deposit and the above-ore series enriched by copper, cobalt, manganese, tin, molybdenum of lower part of the ore deposit and the under-ore series) and this is a reflection of the general geochemical zonation [7]. According to L.N.Ovchinnikov and E.N.Baranov [11] the zonation of the geochemical aureoles in Filizchai is typical for pyrite deposits and according to the distribution peculiarities of typomorphic chemical elements refers to the second type of vertical zonation of the authors' classification as the highest concentration is confined to the ore deposit. Considering the data of these researchers not to be completely substantiated by the endogenic

geochemical aureoles of the Filizchai deposit, A.Z.Akimidze [12] defined the asymmetric distribution of geochemical aureoles: anomalous concentration of element-indicators in the under-ore series and their absence in the above-ore part of the deposit. On this basis, the author advocates a volcanogenic-sedimentary origin for industrial precious metals (Cu, Zn, Pb and so on) deposits. However, many years' research conducted by different authors, including ourselves in the area of copper-pyrite-polymetallic deposits of the Greater Caucasus Eastern segment shows the incorrectness of the ideas of A.Z.Akimidze [12] related to the structure of endogenic geochemical aureoles and especially the conditions of ore deposit formation.

It is noteworthy that Y.T. Dreus [13] studied the primary halos of copper-pyrite-polymetallic deposits of the Greater Caucasus Eastern segment and concluded that one of the typical peculiarities of the investigated deposits is the accumulation of tin and molybdenum in the above-ore halos. However, our research in some deposits of the South slope (Filizchai, Katsdag, Jikhikh-Sagator and so on) showed the author's conclusion to be worthless, i.e. these elements are typical for back zones of lithochemical anomalies. Moreover, the accumulation of molybdenum in the under-ore zone of Filizchai pyrite-polymetallic deposit was earlier mentioned by other researchers as well [11]. Zonal structure of aureoles reflects the high contrast in multiple coefficient of zonation, the value of which varies from 2.0×10^1 in host rocks of Filizchai pyrite-polymetallic deposit (in the above-ore zone aureole) up to 4.2×10^{-1} in the under-ore zone. For the Katsdag copper-zinc-pyrrhotine deposit the values are 7.1×10^{-1} and 3.1×10^0 respectively (Table 3).

Table1. Average amount of rare and noble metals in the main sulfide minerals in the pyritaceous deposits on the South slope of the Great Caucasus (ppm).

Elements	Pyrite	Sphalerite	Galenite	Chalcopyrite	Pyrrhotine
Cd	26.5	1600	25	18	17
In	3.6	49.5	5	22	2.1
Tl	13.6	7	25	3	1.5
Ga	3	15.5	2.9	2.6	2.1
Ge	1.7	2.4	0.9	1.3	1
Se	27.5	11.6	110	11	43.5
Te	3.9	8	40	20	5
Bi	43.5	30	420	100	43
Au	0.62	0.36	0.03	0.7	0.20
Ag	32	45	645	81.5	14.5

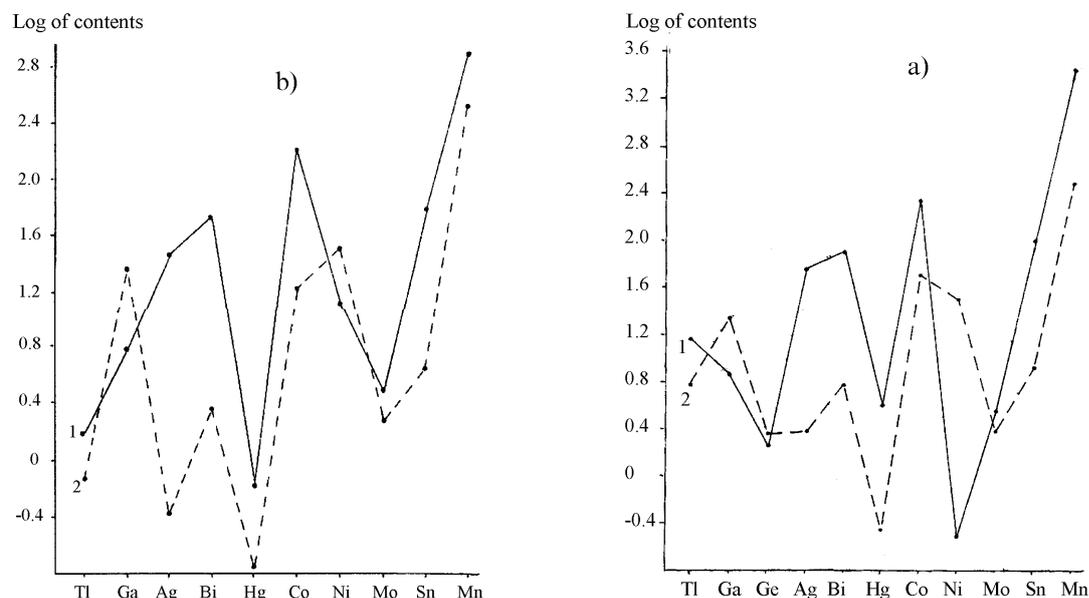


Fig. 1. Graph for comparative characteristics of admixture-elements distribution in pyrite ores (1) and host rocks (2) of Filizchai (a) and Katsdag (b) deposits.

Table 2. Average contents of admixture – elements* in the host rocks of pyrite deposits of Greater Caucasus South slope (ppm) from Azerbaijan area.

Elements	Clayey shales				Aleurosandstones			
	Filizchai	Katekh	Katsdag	Jikhikh-Sagator	Filizchai	Katekh	Katsdag	Jikhikh-Sagator
1	2	3	4	5	6	7	8	9
Tl	7.3 (28)	1.8 (25)	0.9 (34)	2.5 (13)	2.2 (16)	1.6 (14)	0.3 (13)	1.5 (10)
Ga	25 (19)		27.8 (5)	15 (13)	19.6(12)		26.7 (6)	12 (10)
Ge	2.2 (8)	1.4 (9)		2.3 (13)	2.1(2)	0.8 (6)		2.1 (10)
Ag	2.5 (45)	4.0 (16)	0.84(29)		1.6 (21)	2.4 (7)	0.38 (9)	
Bi	6.5 (17)	1.1 (13)	1.9 (29)		6.0 (7)	1.0 (7)	2.9 (9)	
Co	52.9(285)	31.2(24)	13.3(34)	9.2(12)	46.3(41)	31.7(6)	10.6(13)	8.4(12)
Ni	42.5(36)	29.3(6)	31.4(34)	13.1(12)	29.4(15)	22.5(5)	26.8(13)	11.2(12)
Mn	350.3(35)	455(6)	451(34)	1600(12)	327.3(15)	350(5)	729(13)	1475(12)
Sn	9.3(36)	3.8(6)	4.4(29)		2.8(8)	2.5(5)	3.6(8)	
Hg	0.028(111)	1.3(29)			0.013(15)	0.7(14)		
Mo	2.5(18)	1.4(6)	1.5(34)	1.8(12)	1.1(5)	1.2(5)	0.7(13)	1.2(12)
Li	34.5(42)	74(46)	23.4(5)		34.9(7)	60.4(11)	23.6(5)	
Rb	77.9(43)	135.7(46)	112(5)		90.0(7)	60.9(11)	50(5)	
K %	1.67(46)	2.91(46)	2.58(5)		1.87(7)	1.50(11)	1.08(5)	
Na %	0.80(45)	1.07(46)	0.22(5)		1.73(7)	1.26(11)	0.09(5)	
U	1.4(16)	2.5(9)			1.4(7)	1.9(9)		
Th	13.1(15)	6.1(9)			8.4(6)	3.9(9)		

* In brackets – the number of analyses

Table 3. Multiplicative coefficient of zonation in halo vertical section of Greater Caucasus South slope pyrite deposits.

Deposits	Series	$\frac{Zn \cdot Pb \cdot Ag \cdot Tl}{Cu \cdot Co \cdot Sn \cdot Mo}$	Contrast coefficient
Filizchai	above-ore	2.0×10^1	47.6
	under-ore	4.2×10^{-1}	
Katsdag	above-ore	7.1×10^{-1}	4.4
	under-ore	3.1×10^0	

3. Admixture-elements as indicators

In order to define the relationship between the components of the host rocks and the process of ore formation the following has been done: samples taken from across the strike of the main deposit on Filizchai stream were analyzed for several elements (Tl, Ga, Ag, Pb, K, U, Th). It was seen that on moving away from the ore body the concentration of components changes (Fig. 2). For thallium and silver this pattern is expressed clearly, i.e. by moving away from the ore deposit with pyrite-polymetallic composition, the content of these elements in the host rocks gradually reduces: thallium – from 29.1 ppm to 2.5 ppm (nearly by 12 times) and silver from 3.4 to 1.4 ppm (by 2.5 times). A sharp increase in lead concentration is found only in clayey shale from the ore horizon (500 ppm) and the relatively high increase in potassium, uranium and thorium contents – from the contact zone. Uranium and thorium content is very low in the ore itself and this shows that these elements were not brought by the mineral-forming solutions and probably they were leached from the wallrock in the ore formation zone during the initial stages of pyrite formation by solutions under conditions of low acidity [14,15]. As a result, they accumulated more in the hydrothermally modified rocks. Location of the bedded-foliated pyrite-polymetallic ores in the Filizchai deposit and areas of high contents of thallium coincide in space: both are drawn towards the upper part and western flange. Such a kind of interdependence can be observed well by approaching the contact between the ore deposit and the host rocks. In this case thallium concentration in clayey shales with high thallium content notably increases (sometimes more than by 20 times) on approaching the ore deposit (drill hole №№ 379, 602). Filizchai deposit allows us to define factors which are favourable for thallium accumulation in the ore-bearing sandy clayey deposits: clayey composition of sericitized rocks and their location in the above-ore series or ore horizon; nearness of the ore body and the pyrite-polymetallic composition of contacting ore [7]. As a whole among the studied admixture-elements Tl, Ag, Hg and also B, Li, Rb one can find accumulating tendency in the above-ore series, near the ores with pyrite-polymetallic composition. Other group of elements (Co, Sn, Mn, Mo, Bi) is represented by accumulation in the under-ore series, just the same as

in pyrite deposits of Ore Altay and Ural where the latter are typical elements for back zones of lithochemical anomalies [16]. Deeper horizons of sandy-clayey rocks are enriched in uranium and potassium and the higher horizons in thorium above the ore deposit. Increase of silver concentration by several tens of ppm in samples from zones with quartz veins and smashed clayey shales sampled from different wells and mountain workings of Filizchai deposit (drill hole №№ 558, 610, 613, 616, 617, 619, gallery №50) can be observed. In several cases it is accompanied by a considerable increase of gold content (up to 1ppm) and lack of a correlating connection with lead. Nearly in all the samples, the components content (Cu, Zn, and Pb) is small. Undoubtedly, this is a positive influence on this process of contacting pyrite-polymetallic ore which is more silver bearing and also gold – bearing among the textural -mineralogical types of ore deposits. Data concerning the silver rich zones with quartz veins and crumpled clayey, shales allows using them as geochemical criteria for search of pyrite deposits in the sandy-clayey deposits of region. Light-colored rocks of zones with pyrite-polymetallic deposits oxidation are of great importance.

4. Conclusions

More or less stable indicators of gold and silver concentrations in the lower horizons of Filizchai deposit along with the ore forming components, geochemical criteria show the continuation of pyrite-polymetallic mineralization, i.e. prospect of deeper horizons of the deposit. Some concentration increases in the above-ore and upper ore components (Ag, Tl, Hg) in the lower horizon and non-systematic behavior of some typical elements of back zones (Co, Sn) and frontal zones (Zn, Cd) in some deposits and host rocks of Katsdag and Jikhikh-Sagator copper-zinc-pyrrhotine deposits are of importance as indicators of possible new ore bodies at depth.

The distribution peculiarities of such elements as (Tl, Ag, Hg, Sn, Mo and Bi) in the host rocks of pyrite deposits of Greater Caucasus South slope allows us to refer them along with the ore forming components (Zn, Pb, Cu) as indicator elements for search of buried ore accumulations in the Lower-Middle Jurassic sandy-clayey deposits of region. Close dependence between uranium and potassium concentrations in the host rocks

of the Filizchai deposit and also spatial association of the relatively higher contents of radioactive elements with zones of hydrothermal-metasomatic changes in the wallrock in contact with the bedded-foliated and massive pyrite-polymetallic ores; vertical zonation in the distribution of their contents and the Th/U values allows us to use these factors as geochemical criteria for search of pyrite-polymetallic mineralization.

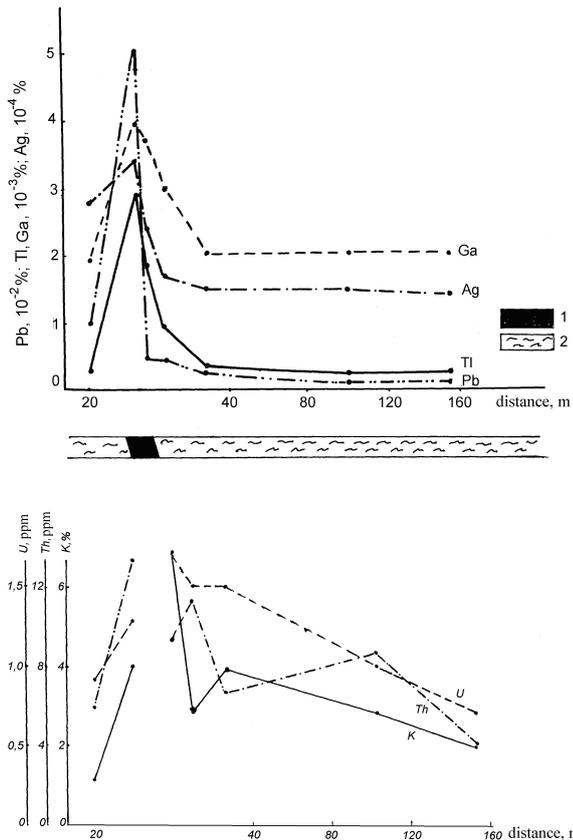


Fig. 2. Dependence of components content in host rocks with reference to distances away from the ore (Filizchai deposit)
Legend: 1 – ore body; 2 – host rock

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