FEMOPHILIC ELEMENTS IN WALLROCK METASOMATITES AND IN ORES OF MESOTHERMAL GOLD DEPOSITS – NEWSLETTER OF MANTLE DEEP

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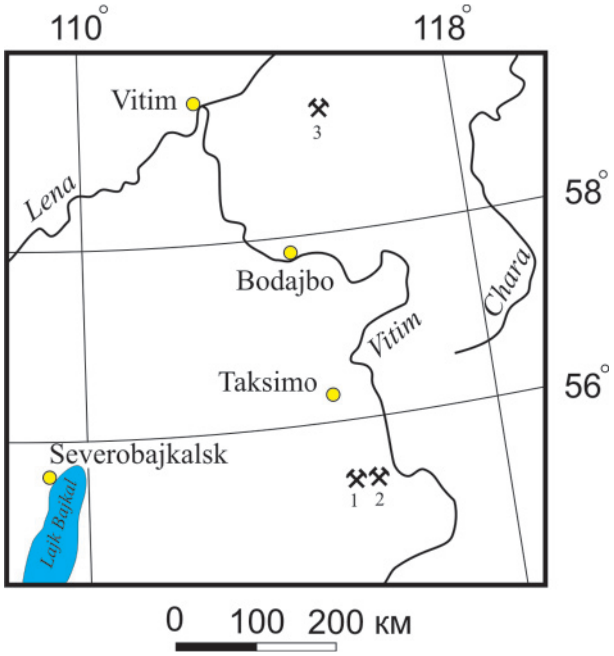
There were found contrast anomalies of femophilic element association: P, Ti, Mg, Mn, Fe, Ca-in back zones of zonal wallrock metasomatite haloes of mesothermal gold deposits in Eastern Siberia (Russia), formed in crystal sole (Irokidinsk, Kedrovsk) and in Proterozoic strats of black silstones (Kedrovsk, Chertovo Koryto), in the nearest (up to 1,5 km) margin of geosutures. Metasomatites in back zones are folded with crystalline silica, sericite, carbonate rock impured with pyrite and represent products of potassic- sulphuric- carbon-dioxide metasomatism with input of recomposed sulphur, carbon dioxide into rocks by disproportionation of alkali with almost complete eduction of Na ant partially of silicon. Femophilic elements grade in metasomatites grows in hundreds …some in hundreds % comparatively to original rocks, but decrease to Clark when removing from solution leading geosutures. The joint with solution femophilic elements are fixed in leucoxene, rutile (Ti), carbonate rock (Ca, Mg, Fe, Mn), apatite (P). Taking into consideration other factors – alternate input of mild alkaline mafic melt and metal-bearing solutions, closeness of isotopic ratio of carbonate oxidated carbon to meteorite standard it was concluded about generation of metal-bearing solutions in deep focus of mafic melt.

Keywords: femophilic elements, crystal sole, black silstones, mesothermal gold deposits, wallrock metasomatite haloes, contrast anomalies, mantle

A qualification of middle-low temperature process of warlock transformations in mesothermal gold deposits is known as potassic- sulphuric- carbon-dioxide metasomatism [1], conditional to input of the listed components with metal-bearing solutions. Together with rock carbonatization and sulphidation almost complete replacement and eduction of comparatively weak base of Na by a stronger kalium is taking place, unlike silicon which is taken away only partially, up to 50 % from the original rock, from high silicon rocks of forming back zones of metasomatite haloes, but it is moving inside them if they are folded by original rocks with low (less than 40–45 %) silica content [2].

The represented data depicts typical petrochemical characteristics of metasomatite process, but its petrochemical essence does not confine to it. In some mesothermal gold deposits of Southern Siberia, – Irokindinsk, Kedrovsk, Chertovo Koryto (picture) there were found wallrock metasomatites and ores, which in near (up to 1,0…1,5 km) margins of solution leading and ore control geosutures are enriched with association of femophilic elements, adding typical triad (K, S, C). All deposits are simple according to geology-genetic characteristics and are formed in Late Paleozoic Age [3, 4]. The accumulated facts are generalized and discussed in the article, the following conclusions are made.

The ore veins of Irokindinsk deposit lay in migmatite- gneissic sole of Muysk brow of Archean basement of the Siberian craton in the eastern footwall of Kelyansk zone of geosutures, of Kedrov deposit- in the Late Proterozoic rock mass of carbon-bearing shale rock of kedrovsk suite and among ultra- metamorphic and magmatic rock of Late Paleozoic mature dome structure in eastern sidewall of Tuldun zone of geosutures. A thick, up to 150 m, flat of vein-disseminated ores of Chertovo Koryto deposit is formed in the zone of decompaction among Early Proterozoic carbon-bearing terrigenous shale rocks of Mikhalovsk suite in sidewall of the geosutures, branching Amandrak geosutures. There are known inter-mineral dikes of mild alkaline dolerites in the deposits, which served as thermal fluid-conductor while mineralization, in consequence of which they were transformed into metasomatites, containing typical for inter-mineral dikes high temperature amphibole-biotite association. [5].



Plan of gold ore deposits: 1 – Irokindinsk, 2 – Kedrovsk, 3 – Chertovo Koryto

In all listed rocks zonal wallrock metasomatite haloes include external, chloritic, albite, internal mineral- petrochemical zones. Thickness of external zone consisting of subzones of weak, mil and intense change (up to 10, 10…20, 20…30 % of newly formed minerals) reaches many hundreds, chloritic- many tens, albite – first, internal – 1,0…1,5 m. In lode deposits the core zone is occupied by aurum- sulphide-carbonate- quartz vein, in Chertovo Koryto deposit the listed zones, except external, are repeatedly alternated in the structure section of the ore shoot.

Mineral associations of metasomatite and mineralization stage are repeated in all discussed deposits and rocks with slight variations of sets of mineral species, more complete in external zone. In generalized structure of rocks of external zone such elements take part silica + sericite + leucoxene + rutile + sulfide + calcite ± apatite ± Mg-Fe-carbonates (dolomite, brown spar, siderite) + Mg-Fe-chlorites (ripidolite, delafossite) ± zoisite-epidote ± petrologen (plumbago, graphitoid) in Chertovo Koryto deposit close toanthracite coal, coak) ± actinote -calamite. In more back chloritic zone actinote and\or calamite disappear. If the latter are missing in external zone, then the sign of transit to chloritic zone is complete substitution of biotite and other colored minerals of the original rocks in it. In the depth of silstones of Chertovo Koryto deposit petrologen is taken away from the part of chloritic zone, neighbor to albite as from more back zones, that's why chloritic zone is divided here into carbon-bearing (with petrologen) and chloritic (without petrologen). In albite zone zoisite-epidotes and chlorites are missing? In internal – albite. Total mass of newly formed minerals is growing in direction to internal margin of each zone and from external zone to internal when number of mineral phases is decreasing from zone to zone. However, the internal zone keeps polymineral and is formed with congeries of silica, sericite, Mg-Fe-Mn-carbonates, leucoxene, rutile, apatite ,sulfides. In chloritic and more back zones the content of gold, silver, arcenic, azoque and other metals is growing, reaching max in internal zone [4].

Nonuniformity in of the original rocks is taken into consideration when estimating mass of the entered into metasomatites and taken away petrogenic elements. Changes of element content in sample increment of one rock does not exceed as a rule10…15 % against average numbers, which much higher than the exactness of chemical silicate test (±0,01…0,02 %). When calculating average the nonuniformity of element content in a selection is decreasing, however it is impossible to estimate accurate inter zonal balance data as it is impossible to determine element content in original rocks, already undergone metasomatism. Taking this into consideration it is assumed that the range of «gain-loss» of elements up to 15 % can be disregarded as insignificant. In those cases when every banded or bedded rock (selection) is presented by one sample, probability of faulty judgment about «gain-loss» is growing for elements with low (less than 0,1…0,2 %) commensurable with the mistakes of content analysis, if the difference of content between the original and changed rocks does not exceed 40…50 %. These restrictions do not apply to inter zonal balance estimations at levels oa many tens…hundreds of per cent.

Simultaneously with growing mass of newly formed minerals, quantity index of intensity of rock chemical structure transformation is increasing – unit weight of the moved (sums of gained and lost) material, – from the first % in external zone to tens % in internal (table). Nonuniformity of element content in rocks gives the most contribution in formation of this index in external zone. It is seen when comparing its values in subzone of a mild change, formed by means of granitic rock of Irokindinsk deposit with relatively equal distribution of chemical elements an banded plagiogneiss Kedrovsk deposit with quite unequal distribution, – 1,2 % in the first case and 7,0 % in the second. It can be judged also when comparing indexes of gain-loss in this subzone of separate chemical elements, – they are lower in granitic rock, but higher in plagiogneiss.

All the discussed metasomatite haloes have the marked above typical petrochemical characteristics: inflow in them with metal-bearing solutions K, S, C, take away from them parts Si, disproportionation of alkali. In some haloes among rocks with high content of kalium additional mass of this element did not stay in metasomatite in accordance to detected principle [2, 6], according to which the more quantity of gained element moves in the forming metasomatite into solid phase the less its content in the original rock, and vice versa. In apo-slate and apo-gneissic haloes alluminium is redistributed – from rocks with relatively high content into rocks with low.

In addition to the mentioned six chemical elements (Ca, Mg, Fe, Ti, P, Mn) in all haloes strong significant gain is discovered, growing from external zone to internal. The latter exclude their redistribution between haloe zones, but proves inflow with metal-bearing solutions from outside.

Table

Balance (gain-loss in per cent) of petrogenic elements in zonal wallrock metasomatite haloes of mesothermal gold deposits in Southern Syberia

Mineral zone, subzone	Chemical elements													Δ
	Si	Al	K	Na	S*	Co	Ca	Mg	Fe^{2+}	Fe^{3+}	Ti	P	Mn	
1. Irokindinsk deposit 1.1. Migmatite granite, AR (3)														
Em(5)	0	0	–10	–10	+	20	20	0	0	10	10	50	–60	1,2
Ei(6)	0	0	–10	0	+	220	70	30	30	70	20	110	0	3,1
Ch (9)	–10	10	–40	40	0	500	70	60	0	60	–10	210	–50	6,9
A (8)	0	0	–20	–10	+	870	10	60	20	50	70	250	10	4,5
In(7)	–10	10	20	–90	+	2400	200	220	100	230	250	650	30	18,8
1.2. Felsitic micrigranite-porphyry, PZ3 (2)														
Ch (4)	–10	10	10	0	–60	140	120	180	170	60	280	190	210	12,6
A (6)	–30	10	70	–50	20	300	240	330	330	80	500	310	330	27,0
In(6)	–30	20	160	–90	1900	390	350	390	210	450	520	230	360	36,8
2. Kedrovsk deposit 2.1. Almandine-2mica plagiogneiss, PZ3 (1)														
Em(1)	–2	2,8	66	–55	–49	–48	–14	10	44	37	–12	143	–27	7,0
Ch (1)	–4	8,4	14	–21	160	–27	36	–48	22	35	10	68	–35	6,0
In(1)	–48	–46	27	–96	2140	1330	716	439	65	61	98	653	42	45,0
2.2. Quartz diorite, granodiorite, PZ3 (6)														
Ch(16)	0	0	0	0	1010	940	0	0	0	–10	0	0	10	4,0
A (6)	–10	–10	20	–10	3170	2070	30	50	60	–30	90	50	40	12,0
In(1)	–50	–20	40	–80	4270	4700	220	240	170	320	170	160	240	41,0
Carbonated feldspathic-quartz slate of kedrovsk suite, PR2 2.3. Meta silty sandstone (1)														
A (1)	–17	4,9	248	–34	+	1905	33	1053	282	340	82	300	374	18,0
In(1)	–39	8,8	445	–93	+	6913	880	1781	447	125	73	672	347	43,0
3. Chertovo Koryto deposit Carbonated feldspathic-quartz slate of kedrovsk suite, PR1 3.1. Coarse meta silstone(5)														
C (2)	0	0	0	–10	–30	–10	50	20	0	30	10	0	0	2,9
Ch (8)	–20	–30	–30	–70	120	1400	1180	100	70	10	540	840	560	29,7
In(1)	–40	–30	–10	–90	0	2800	1920	170	30	–90	570	900	2110	43,4
3.2. Fine-grained sandstone (5)														
C (1)	0	0	–30	80	180	40	30	10	0	–20	30	–30	100	3,5
C (3)	0	10	–20	10	130	100	80	120	30	70	20	0	150	6,5
Ch (6)	–40	0	–20	–70	430	1910	1400	330	160	30	820	890	1750	34,9
In(1)	–30	–10	–10	–90	10	1980	1260	260	110	180	790	870	3620	32,5
3.3. Consertal sandstone (1)														
C (1)	0	0	70	–70	1130	10	–40	110	60	90	30	–50	0	7,94
Ch (4)	–30	–10	0	–85	1640	1370	510	420	240	80	840	450	600	31,4
In(1)	–50	–30	–10	–90	6570	3180	1300	690	250	490	490	640	4600	55,6

Notice. 1) Mineral zones and subzones of wallrock metasomatite haloes: Em, Ei – subzones of mild and intensive changes of external zones, C, Ch, A, In – respectively carbonated, chloritic, albite, internal zones. 2) S^{*} – sulphide sulphur, C_o – carbon oxidized, + -gain of S when content of it in original rock is lower than test sensitivity. 3) Within brackets – number of samples, taking part in average calculation. 4) Δ – unit weight of moved (gained and lost) material in per cent to the material of the original rocks in standard geometric volume 10000 $Å^3$. 5) Balance of petrogenic elements in metasomatite haloes is calculated basing on petrochemical recalculations according to volumetric-atomic estimation of complete chemical silicate analysis of samples attributing difference of number of atoms of elements in standard volume of metasomatites of mineral zones and corresponding original rocks to the number of atoms of elements in the standard volume of the latter. 6) Complete chemical silicate analysis of rocks is made in the Central laboratory of production geological association «Zapsibgeology» and in the Western Siberian test centre (Novokuznetsk) under the supervision of I.A. Dubrovskaya and G.N. Yuminova.

In absolute terms content in metasomatites of back zones reaches in per cent (in brackets – ordinary content in the original rocks) CaO – 14 (1…3), MgO – 6…9 (3) FeO – 10 (3–5), Fe_2O_3 – 2,5 (0,5…1), TiO_2 – 4,5 (0,5…0,7), P_2O_5 – 1,7 (0,15…0,35), MnO – 1,3 (0,02…0,07). The gained elements are fixed I the following minerals of metasomatites: K – in sericite, Ca, Mg, Fe, Mn – in carbonates, chlorites, epidote, Ti – in leucoxene, rutile, P – in apatite.

The represented data gives additional possibilities in specification of geologic-genetic essence of hydrothermal gold producing process.

The repetitiveness in full volume in different deposits and rocks of structure and mineral-petrochemical characteristics of wallrock metasomatite haloes , in black-shale depth composing vein-disseminated ore deposits, appears regular, reflecting (additionally to other facts [4, 5]) genetic homogeneity of gold deposits of «non slate» and «slate» typed, that is formation of these and those as a consequence of metal-bearing solutions functioning, which have authentic physical-chemical and thermodynamic characteristics.

The majority of petrogenic elements, except Si, Al, Na, came from outside with metal-bearing solutions. Taken away from high-silicon rocks silicon earth (from 1 cubic meter of the rock with mass up to 0,8 t) migrated in haloes, so to say, in the content of soluble salts of silicic acid, filling its deficit in low-silicon rocks which underwent transformations and composing the basis of quartz veins and veinlets. Necessary for quartz resorption, for example, in quartz sandstone and silstones of black shale depths, freeing space for deposits of comparable mass of carbonates, deposits of petrologen in veinlets, the conditions were provided by alkali recovery form of early portions of solutions, from which earth silicon, oxided forms Ti (rutile, leucoxene) deposited into solid phase after inversion of early form into acid, oxidative. Obviously, taking into consideration the extent of rocky earth silicon resorption, its inflow with solutions from outside is excluded. Alum earth, as it was marked, was redistributed from high to low- alum earth [2]. Na was taken away from the haloes.

In reconstruction of geological dependence of mineralization we should take into account the inflow of association oa femophilic elements into haloes. An inseparable couple in endogenetic processes titanium – phosphorus presents special interest, their concentration and mass in connection with ferrum in magmatic deposits reaches industrial value. For example, in magmatic and in initiated by them hydrothermal processes apatite-titanium-magnetite ores are formed in basites (Volkovskoe deposit in the Urals) and in carbonatites of ultrabasic-alkali complexes (Kovdorskoe at Kola Peninsula, Polabora in RSA), nephelite-apatite ores with high concentration of sphen – as a consequence of differentiation of ultrabasic alkali meltings (Khibinskoe deposit at Kola Peninsula). Genetic connection of production-scale agglomeration and increased against Clarke contents of the total of the discussed elements with basite, ultrabasite and alkali rocks, absence of the formed increased concentrations of these elements in combination (Ti, P, Mg) in the substance of Earth crust in connection with crust magmatite, aqueous, metamorphic processes points at their mantle sources. Suppositions for phosphorus, titanium and other elements loss from the mantle are proved by the results of mantle xenolith study and the real loss onto Earth surface – by the participation of their combination in the contents of gas volcano with mantle supply and solid products of volcanic activity [7].

Increased values of Ti, V, P in wallrock metasomatites and ores are noticed in several other hydrothermal gold deposits of Southern Syberia and the world. In the Soviet deposit of Yenisei range, formed in black siltstone of Proterozoic Uderei suite, rutile, titanic Iron ore, apatite are mentioned by N.V. Petrovskaya [8], which she thought were idiogenous to slate minerals, redistributed while mineralization. Later their was an opinion about titanium gain from outside [9]. In Late Paleozoic deposit Sukhoi Log of Leninsky region in back zones of AA deposits, laying among black silstones of Late Proterzoic Dogaldynskaya and Khomolkho suites, contents of MgO is 2…5 times, P_2O_5 two times higher than their contents outside ore bodies [10], and blue and pink apatite is in quartz veining [11]. Ores of the Kalgurili deposit in Australia [12] are reach in vanadium-bearing muscovite, Hemo in Canada [13] – in association with rutile, El Dorado in California [14] – roscoelite, Cripple Creek in Colorado [15] – roscoelite and rutile. Anomalies of titanium are discovered in gold ores and metasomatites of deposits Mangaluru [16], Colar [17], in India, Connemarra and Katheleen in Western Australia [18], Obuasi in Ghana [19].

The foregoing together with mantle marks of carbon isotopic ratio of metasomatite carbonate and sulfide sulphur is complied with a number of other [5]. The participation in mesothermal gold deposits, including «slate» type, pre-ore, inter-mineral and late-ore dikes of mild alkali dolerites underlines simultaneous functioning of the connected by transportation routes- deep splits of mantle, low-crust chambers- mild alkali mafic melt and metal-bearing solutions on the top of Earth crust at stages of their mixing with deep immersed by groundwater aquifers. Chambers of mild alkali mafic melt, splits, forming deposits compose mesothermal gold producing systems, – total of all factors is in the complex of evidences of basalt-genic concept of mineralization, supposing generalization of metal-bearing solutions in chambers of mild alkali mafic melts.

In future study of femophilic specialization of gold-bearing metasomatites and inclusion into analysis hydrothermal deposits Au, U, Sb and other metals we should take into consideration comparably fast decrease till Clarke concentrations of femophilic elements in metasomatites while removing from deep splits, thus, local but not the total deposit position of their anomalies, possible absence of the latter in different deposits because of inversion of favorable for transportation of phosphorus, titanium of alkali mode solutions to acid sub-ore stages or element deficit in generation chambers, and other factors, complicating the research.

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