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Rear polymineral zone of near-veined metasomatic aureole in mesothermal Zun-Holba gold deposit (Eastern Sayan)

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Abstract: Unique data of the mineralogical and petrochemical zoning of near- veined metasomatic aureole of mesothermal Zun-Holba gold deposit are presented and discussed. It was established that mineralogical and petrochemical zoning order is based on Korzhinsky theory describing the differential component mobility. However, the internal polymineral zone structure of metasomatic column in Zun-Holba deposit does not comply with Korzhinsky concept describing the mono-mineral composition of axial (ore-bearing quartz veins) and binary-mineral rear (quartz-sericite) zones. Mineral zoning complication is governed by component diffusion (from fractured fluid to pores) and pulsation mode of metalliferous fluid input into the mineralization area.

1. Introduction

Since the 50's of the twentieth century, most experts accepted the non-alternative Korzhinsky theory of metasomatic processes, particularly, metasomatic zoning [1]. However, there still exists a misunderstanding in assessed mineral composition of metasomatic rocks in the axial zone (quartz vein) and adjacent rear zone involving zonal near-veined (wallrock) metasomatic aureole. It is a well-known fact that metasomatic zoning theory embraces Korzhinsky concept of differential component mobility determined by thermodynamic and physico-chemical regimes in fractured porous rock-fluid mineralization systems. The bulk of rock-forming components include most mobile (H_2O, CO_2), highly mobile in all conditions (S, Cl, Na, K), mobile in certain conditions (O_2, Si, Mg, Ca, Fe) and inert (Al, P, Ti).

According to this theory, in near-fractured metasomatism, where invading external metalliferous fluids into cracks intensify rock alteration, sequential transformation of components from inert into mobile state accompanied by mineral dissolution in parent rocks occurs. According to Korzhinsky, when stagnant conditions merge into a mobile state and pore solutions with filtrating fluids from cracks form hydraulically connected system, the components diffuse into the fractured solutions and are removed. The remaining minerals in the columns decrease to the extent of monomineral axial zone. Zonal metasomatic columns are formed, where in each frontier mineral zone there is one mineral less comparable to less altered rocks in adjacent closer frontal zone

However, more and more attention is focused on the fact in natural, for example, gold-bearing beresite columns with medium-low temperature (380...250°C), potassium-sulfur-carbon dioxide metasomatism of binary-mineral (quartz-sericite) compositions adjacent to the axial rear (beresite) zone does not occur [2]. The contradiction of natural columns to their theoretical model would have required a thorough investigation of the structure of both beresites and near-fractured columns, as well as other acid metasomatites – greisen, argillizated rocks, argillizites, propylites; however, if there exists such a contradiction then its reasons should be studied and metasomatic zoning theory should be fully defined. In this case, there is still a shortage of mineral zoning descriptions of natural hydrothermal metasomatic columns. The theoretical model of metasomatic zoning with monomineral axial (quartz) zone characterized as natural ones has been described in different publications [3,4]. Based on the chemical analysis data [3,4], it was found that in the adjacent to axial "quartz-sericite (muscovite) zone" the columns formed from carbonate-free and sulfide-free granodiorites. As CO_2 and recomposed S (up to tenths of w. %) are evident in this zone, this indicates the fact that in addition to quartz and sericite minerals, there are two other mineral classes – carbonates and sulfides. Beresite according to its mineral-chemical pyrite-quartz-sericite-carbonate composition is often associated with metasomatites, but due to the fact that it is not found in near-ore altered quartz-sericite and quartz as described in the metasomatic zoning theory [5], this fact in itself is often neglected. The above-mentioned fact is based on the general concept that the polymineral structure of metasomatic columns adjacent to quartz-vein zone is naturally-formed which could be governed by either underdevelopment process or complex evolution of thermodynamic and physico-chemical fluid regimes, filtrating in wallrock pore spaces [6-8] which, in its turn, is a characteristic stagnant regime of pore-filling solutions. Therefore, the transportation of components in wallrocks is possible not by fluid flow, but by their concentration diffusion. To explain the polymineral metasomatite composition in a column rear zone based only on the above-mentioned facts is rather ambiguous and, in this case, requires further investigation.

Excluding the ambiguity discussed issue and defining some aspects of the existing metasomatic zoning theory is impossible within the walls of either a classroom or laboratory. This could be explained by a detailed study of natural near-ore metasomatic columns in hydrothermal deposits of metallic mineral resources, accumulation of experimental data on the mineral zoning structure of hydrothermally altered rock aureoles in wallrock space and research facts proving the formation conditions of rear and axial metasomatic column zone mineral composition. It should be noted that the mineral zoning sequence, i.e. the succession of mineral zones in columns, could be described by the differential mobility of components. This paper involves the detailed investigation of near-veined metasomatic aureole in Zun-Holba mesothermal gold deposits.

2. Results and discussion

The deposit is located in the S-E Eastern Sayan in the watershed of the riverheads of Urik and Kitoy rivers. This deposit is included in the Urik-Kitoy gold-ore zone controlled by Okino-Kitoy system of northwest trending deep faults, separating Gargan ridge of Archean Siberian platform basement from Proterozoic and Paleozoic margins. The deposit embraces in the south- gneiss-granite Gargan ridge; in the north – Middle Paleozoic Ambartogolsk massif granitoids (400 – 420m.a.) [9] and Holbinsk (Sumsunursk) complex; and host ore bodies of Riphean-Vendian volcanogenic-sedimentary formation in Ilchirsk suite, all of which are interlaying within Holbinsk fault, found in deep faulted Okino-Kitoy system. This formation of up to 400m. includes alternating layers and bands of sandstones, siltstones, limestones, mafic and acid effusive rocks, quartzite, black shales. These rocks have been subjected to intensive folding deformation –this multi-folding process is combined with intensive hydrothermally altered rocks throughout the thickness, including granites adjacent to volcanic-sedimentary formation of Ambartogolsk massif, hosting gold-bearing veins. Subvertical orientation of stringer-porhyry ore deposits is analogous to oriented tectonic joints in subvertical deep fault zones. Near- veined metasomatic column in Ambartogolski massif plagiogranites includes the following mineral zones (table 1).

Table 1. Mineral zoning of wallrock metasomatic aureoles in mesothermal Zun-Holba deposit.

Mineral zones	Rock mineral composition (italicized minerals fading out to outer rear zones)
Frontal	*quartz+ sericite+ calcite+ leucoxene+ rutile+ ilmenite+ magnetite+ albite+ chlorite+ zoisite+ epidote+* <u>biotite (parent rock)</u>
Epidote-chlorite	*quartz+ sericite+ calcite+ leucoxene+ rutile+ ilmenite+ magnetite+ albite+ chlorite+* <u>*zoisite-epidote*</u>
Chlorite	*quartz+ sericite+ calcite+ leucoxene+ rutile+ ilmenite+ albite+* <u>*chlorite*</u>
Rear (beresite)	*quartz+ sericite+ calcite+ leucoxene+ rutile+ sulfides+gold+silver*
Axial (quartz vein)	*quartz+ calcite+ sericite+ sulfides+gold+silver*

The frontal zone with a thickness of several tens meters embraces massive coarse-grained (grain size of up to several mm) gray plagiogranite composed of randomly oriented narrow tabular plagioclase crystals (andesite up to 60 vol. %) intertwining with gray and dark gray quartz (up to 25 vol.%) incorporated into isolated large oval grains of nested lenticular aggregates and brownish biotite grains and flakes (up to 30 vol.%) with impurities of xenomorphic orthoclase grains, single microcrystals of hypersthene, sphene, zircon, apatite. Rocks preserve a hypautomorphic structure – weakly hydrothermal alteration with new growth volume of up to 10 %. This alteration is reflected in the formation of thin albite rims on the plagioclase crystal periphery corroded by ultimate quartz, in uneven, usually weakly sericite replaced plagioclase crystals incorporated with calcite, variolated zoisite segregation and mature epidote. Brownish biotite forms large flakes (up to 3 mm) and accumulation of small pale green chlorite- substituted scales often incorporated with epidote. Biotite cleavage results in leucoxene-rutile accumulation and lenticular quartz segregation.

In the several meter epidote-chlorite zone there are no biotite and pyroxene – they are dissolved on the inner frontal zone boundary. Rock alteration intensity has increased due to increasing neocystallisation up to 25...30 vol. %, basically, epidote, chlorite, sericite. Because of abundant green minerals the rocks have a green tint. Hypautomorphic structure groups with rounded elongated clastic grains.

Short-columnar (up 1 mm) plagioclase crystals include heavy, usually not massive and, rarely, impregnated sericite and/or and / or variolated zoisite segregation (up to 30 vol.%), partially epidote-substituted in microcracks. Although polysynthetic plagioclase twinning is veiled, it is sometimes visible. On the periphery some plagioclase crystals are rimmed by pure albite bands, indicating plagioclase deoxidation. In sericite-substituted plagioclase generating silica excess is crystallized into thin fine-grained quartz aggregates within the crystal rims, whereas, the boundaries between quartz aggregates and plagioclase crystals are not distinct, but can be visible only under a microscope.

Quartz is large (up to 2…3 mm) and suboval segregations, but the number of fine-grained aggregate intergrowths, being nests, lenses and veins, increased. There is little pale green chlorite, which form as isolated rare flakes up to tenths of a millimeter or as a cluster of up to 3 mm in diameter. Sericite-substituted chlorite associated with leucoxene (rutile), quartz, rare magnetite and ilmenite grains are found along the cleavage. There is an insignificant impurity of xenomorphic calcite grains can be observed in the rocks. In the chlorite zone within the first meters there is no epidote-zoisite, but the rock still has a pale green color because of chlorite. There is a massive structure, the coarse crystalline texture predominately includes rounded elongated clastics with hypautomorphic relics.

Plagioclase of up to 55...60 vol.% is practically substituted by sericite including impurities of xenomorphic quartz and calcite grains or without. Under conditions of complete sericite aggregate-substituted plagioclase, these clusters preserve their former crystal form. There are rare preserved xenomorphic orthoclase grains, which are poorly sericite- substituted and pelitized.

Quartz (up to 35 vol. %.) with coarse, sometimes suboval grains, can be found in fine-grained aggregates. Coarse grains have smooth, linear or even winding contour; the aggregates develop quartzlike structure with toothed bay-like grain intergrowths. Green sericite-substituted chlorite flakes (up to 2…3 vol.%, size to tenths millimeter) are found along the cleavage, where fine-flaked muscovite incorporated with fine xenomorphic grains (hundredths of mm) of calcite (up to about 4…5 vol.%), quartz, ilmenite, leucoxene and rutile.

Well-developed metasomatites in the quartz-vein exocontacts are greenish-gray fine-grained massive porphyritic rock with rounded elongated clastic mass. Alternating composed sericite and quartz, including proportionally 50 * 50 vol.% with impurities of fine xenomorphic grains of calcite (up to 5 vol.%) and comparably sized (to tenths of a mm) crystals of pyrite (up to 2 vol.%) and leucoxene (rutile).

Porphyritic-like rocks (up to 3 mm) are a result of oval dark gray quartz grains comparable to those in plagiogranites immersed in fine flaked sericite, quartz-sericite mass. The grains have a smooth non-corroded contour in contrast to fine (up to tenths mm) quartz grains, having jagged, crow contours and, intergranular gradation forming clusters of subisometric, lenticular, vein-lenticular sericite mass.

Substituted plagioclase crystals by pure sericite clusters preserve their shape. Sericite clusters having substituted pigment minerals – chlorite, epidote and further biotite are contaminated with impurities of leucoxene and rutile. Pyrite crystals are usually rimmed by quartz grains, including flame-shaped ones.

According to the mineral composition these rocks are classified as beresite. Quartz-sericite rear zone rimmed axial monocomponent gold-ore with carbonates, sulfides, gold-bearing quartz veins in the metasomatic halos of deposits were not found. Formation of calcite, pyrite and other sulfides, abundant potassium mica – sericite in rear (beresite) zone of near -veined metasomatic columns formed in carbonate-free, sulfide-free plagiogranites indicate the fact of potassium, carbon dioxide, sulfur, metals input (diffusion) [10] from fractured metal-bearing fluids into porous fluids of wallrocks, that is potassium- sulfur- carbon dioxide metasomatism type.

3. Conclusion

Described metasomatic zoning was developing in accordance to the phenomenon of differential component mobility – highly intensive rock alteration, where one mineral dissolved on the inner boundary of each of the forming zones sequentially– biotite, epidote, chlorite, albite, while reacting mobile components diffused into fracture solutions and/or incorporated into the forming minerals.

Two-component and mono-component composition of column inner zones is not developed due to the invading counter diffusion with component fluids, from the fractured fluids in pores, sericite and their further incorporation into rock masses of sericite, calcite and sulphides. Counter-diffusion of components complicates the mineral composition of the inner metasomatic column zones. It is also involved in the polymineral composition formation inner mineral metasomatic column zones the proof of which is the pulsating regime of hydrothermal systems [11], as a result of which, there exists a continuous spatial alignment of mineral associations and complexes – derivatives of following fluids significantly different from the dissolved solid compositions. Korzhinsky metasomatic zoning theory was developed for continuous outflowing fluid from the generation source throughout the process. The above-described metasomatic columns embrace two metasomatite formations – beresite in inner zones and propylitic – in peripheral zones, which could be found in many gold deposits [13].

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