

METASOMATIC ALTERATION OF ROCKS IN THE TAMDYBULAK–BALPANTAU AREA AND ITS RELATIONSHIP WITH GOLD MINERALIZATION

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ABSTRACT

This paper presents the results of a study of the mineralogical and petrographic features of the metasomatic formations of the gold deposits of the Tamdybulak–Balpantau area. It is shown that the development of various formational types of alteration (propylites, beresite-listvenites, etc.) accompanies the formation of multistage gold mineralization, both being products of a single episode of mineral formation.

Keywords: *Tamdybulak–Balpantau Area, Metasomatites, Propylites, Beresite-Listvenites, Petrographic Characteristics, Gold Mineralization, Stages of Ore Formation.*

INTRODUCTION

The study of the metasomatic formations that accompany the majority of endogenous deposits is of considerable interest, both theoretically and practically [4, 6, 8]. The theoretical significance of metasomatite research lies in the possibility of obtaining highly important information on the conditions under which these rocks, and the ores associated with them, formed. The practical interest lies in the fact that these rocks constitute one of the most reliable prospecting criteria in the search for hydrothermal ore deposits [5, 7].

The aim of this work is a detailed investigation of the characteristics of metasomatic formation, identification of the conditions of their formation, and the mineralogical and petrographic features of the near-ore altered rocks.

MATERIALS AND METHODS

Research methods: The study employed both traditional methods — description of hand specimens, optical examination of thin and polished sections with photographic documentation, mineralogical analysis of heavy-mineral concentrates, and monomineralic separation. To clarify the conditions of formation of the metasomatic formations, detailed mineralogical and petrographic descriptions were made of thin sections of the primary rocks and of the near-ore alterations developed after them.

Objects of study: The objects of study are the gold deposits and ore occurrences of the Tamdybulak–Balpantau ore field, located at the north-eastern termination of the Tamdytau Mountains in the Central Kyzylkum. In the course of the study, the distribution patterns of major and associated elements in the rocks and ores of individual sectors of the area (the Balpantau deposit, and the Kyzyltash and Taiman ore occurrences) were examined, and, on the basis of statistical processing of the results, prognostic-prospecting criteria were identified.

Geological setting of the study area: The study area is located in the north-eastern part of the Northern Tamdytau Mountains [2]. A distinctive feature of this area is the occurrence of gold mineralization in volcanic rocks of intermediate, and more rarely mafic, composition, which is not typical of deposits of the Central Kyzylkum region [3].

The volcanogenic-sedimentary part of the section is represented for the most part by carbonaceous sericite-quartz-albite tuffaceous shales, tuffaceous siltstones and tuffaceous sandstones. A minor part of the rocks is represented by lavas and clastolavas of andesites and andesite-basalts, and by carbonate rocks in the form of limestones and calcareous sandstones. Rocks of subvolcanic origin are represented by stock-like bodies of andesites and andesite-basalts, distributed in the central and north-eastern parts of the area.

Intrusive magmatism in the Tamdybulak–Balpantau area is of limited extent and is represented mainly by dyke formations assigned to two complexes: the North Nuratau complex (conventionally Permian gabbro-diorite-lamprophyre) and the South Tien Shan complex (Middle–Late Triassic lamprophyres of alkaline gabbroids; F.K. Divaev *et al.*, 2002).

The principal structural unit of the Tamdybulak–Balpantau area is a volcano-tectonic graben. Most of the graben is overlain by a thick cover of Meso-Cenozoic rocks, with only a small part exposed, corresponding to the Northern Tamdytau. In the covered part the graben is traced by rocks of increased basicity — subalkaline picrites and microbasalts — whereas in the exposed part it is traced by Middle Carboniferous basalts [2].

RESULTS

The host rocks of the Tamdybulak–Balpantau ore field have been intensely transformed as a result of regional and local metamorphism. Local, or contact, metamorphism is expressed in hornfelsing of the sandy-shaly rocks and marmorization of the carbonate sequences. Clastic rocks — feldspar-quartz sandstones — lose their clastic texture during metamorphism. As a result of recrystallization of the clasts, the cement becomes a mixture of sericite and carbonate. Relict feldspar is frequently replaced by sericite. In addition, newly formed feldspar appears in the form of veinlets and clusters; quartz acquires undulose extinction, and a characteristic mosaic disintegration of grains develops. Practically all the carbonate rocks developed within the ore field are marmorized to varying degrees. In addition to hornfelsing and marmorization, a significant part of the essentially terrigenous rocks is biotitized, apparently owing to the proximity of a granitoid massif at depth beneath the area.

Hydrothermal-metasomatic alteration and gold-ore mineralization are recorded, to varying degrees of intensity, in all the lithological varieties of the Paleozoic section making up the area.

The most a really extensive alterations are propylitization and beresitization-listwaenitization of the rocks. The principal changes associated with the latter are silicification, sericitization and carbonatization accompanied by sulphide mineralization, whereby the rocks acquire a lighter coloration (Fig. 1).

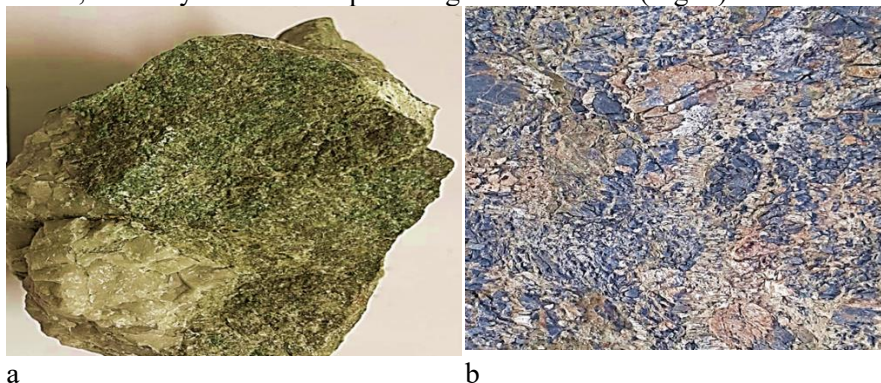


Figure 1. Zones of beresite-listvenite near-ore alteration in and esitoid tuffaceous sandstones with nest-like carbonatization of the rock (Maysky occurrence; hand-specimen photograph, a); zones of quartz-sericite and quartz-carbonate-sericite metasomatic alteration with silicification (Balpantau occurrence; thin section; magnification $\times 64$, crossed polars, b).

Propylitization, as well as beresitization-listwaenitization of the rocks, appears to be of earlier origin, since within the ore-bearing zones the superposition of carbonatization, silicification, sericitization and sulphidization upon these alterations is clearly observed.

The processes of propylitization and beresite-listvenite alteration are widely developed in subvolcanic, effusive and tuffaceous-sedimentary rocks of basalt–andesibasalt composition. All these zones of alteration are accompanied by weak, disseminated pyritization of the rocks.

Quartz-sericite and quartz-carbonate-sericite metasomatic alterations with pyrite have a distinctly cross-cutting, superimposed character and are confined mainly to zones of cross-cutting and sub-concordant fault-tectonic

structures, as well as to the near-contact parts of subvolcanic and sill-like bodies with the host rocks. Vein-veinlet zones are accompanied by pyritization; pyrite develops mainly along veinlet selvages, along fractures, and along the schistosity of carbonaceous-micaceous-quartz shales, siltstones and sandstones.

Pre-ore alteration of the rocks belongs to the propylitic formation. In some cases the metasomatic alteration affects effusive rocks of intermediate and mafic composition, while in others it affects aluminosilicate sandy-shaly deposits. The complex of mineral associations displays a number of distinctive features. The rocks are massive and cut by quartz veinlets, often carrying sulphide mineralization. The textural-structural features characteristic of this rock type are usually absent, and newly formed feldspars are replaced by carbonate, sericite, or a mixture of minerals; the carbonates are in turn replaced by limonite, which is frequently leached in the upper oxidized zones, causing the rocks to acquire a porous texture (Fig. 2).

Pre-ore alteration of aluminosilicate rocks is characterized by the development of metasomatic quartz, sericite, pyrite and feldspar, with a subordinate amount of carbonate.

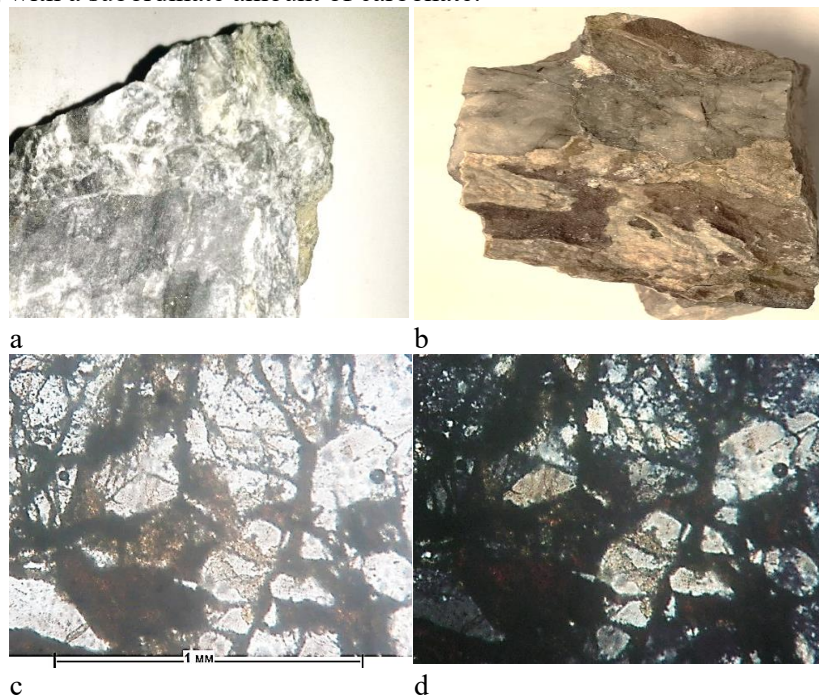


Figure 2. Metasomatic replacement of andesite porphyrites by carbonates (a) and by chlorites (b), producing a more porous texture (a–b, hand-specimen photographs; Taiman occurrence); intensely silicified zone of beresite near-ore alteration, with cataclased quartz and sulphide mineralization developing along its fractures (thin section; c — plane-polarized light, d — crossed polars; Balpantau occurrence).

The composition of the mineral association is not constant and depends on the composition of the parent rocks. Zones of altered rock are controlled by faults, fracturing and rock deformation. At the surface, the zones are marked by bleaching, carbonatization and feldspathization.

The terrigenous rocks are affected by beresitization, and their composition is fairly uniform: quartz, sericite and pyrite, with clastic minerals largely lenticular and recrystallized. Feldspars are replaced by mica and carbonate. The rocks are intensely silicified, the quartz is cataclased, and sulphide mineralization develops along its fractures (Fig. 2, c–d).

In the carbonaceous shales sericite predominates, often forming almost monomineralic, linearly elongated aggregates parallel to the schistosity. Carbonaceous matter and leucoxene are concentrated together with it. Carbonate replaces the clay-sericite aggregate, in which a banded texture, emphasized by carbonaceous particles, is frequently traceable.

A characteristic feature of the volcanogenic-sedimentary rocks of the North-Eastern Tamdytau in general, and of the Tamdybulak–Balpantau ore field in particular, is their intense dislocation and metasomatic alteration. The earliest and highest-temperature process was intense actinolitization and epidotization, widely developed in basalts and andesite-basalts (Fig. 3). This process may be assigned to a relatively high-temperature actinolite-epidote facies of alteration.

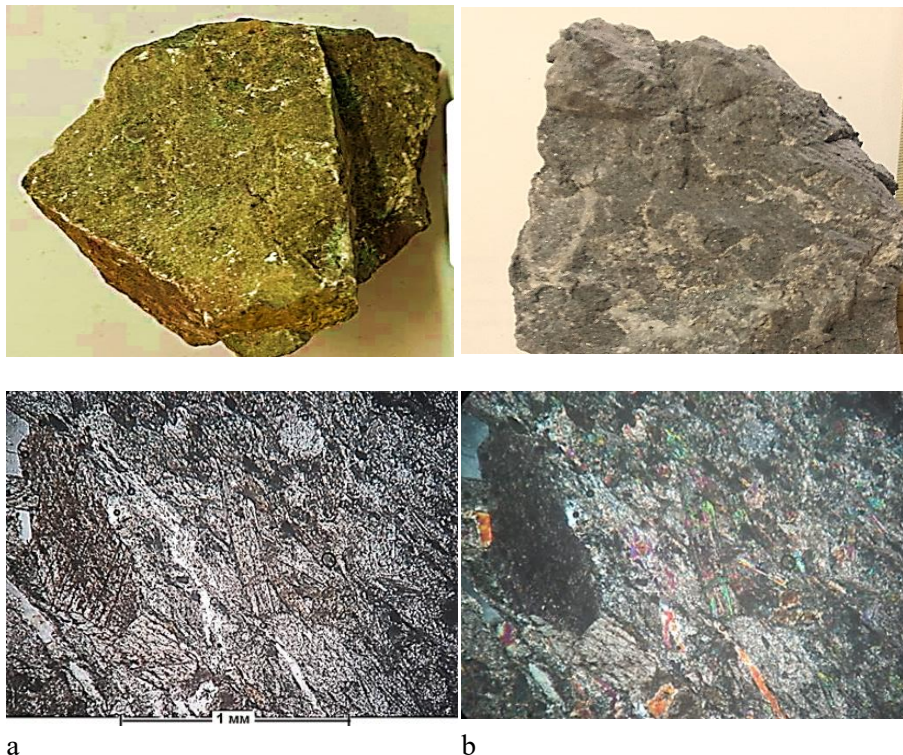


Figure 3. Intense propylitization (actinolite-epidote replacement) and carbonatization of andesite-basalts, occurring as discrete zones (a) and as nest-and-vein formations (b); Balpantau occurrence; propylites of actinolite-chlorite-carbonate composition developed after andesite-basalts, Maysky occurrence (a — plane-polarized light, b — crossed polars).

Lower-temperature metasomatites of epidote-chlorite-albite-carbonate and chlorite-sericite-albite-quartz-carbonate composition, with an admixture of tourmaline and pyrite, belong to the propylite-beresite formation of medium- to low-temperature metasomatic alteration. Prismatic actinolite grains, splitting into fibres at their ends, alternate with lenticular-lamellar chlorite segregations and rarer veinlet-lenticular segregations of quartz and calcite along the schistosity of the rock. Mineralogical composition, in %: actinolite 55–60, chlorite 30–35, quartz 5–10, calcite 2–3.

Listvenites are developed mainly in the northern and eastern parts of the ore field, forming chiefly after subvolcanic and effusive basalts and andesite-basalts. In addition, apogabbro and apoultrabasite listvenites occur in the area after dyke and dyke-like bodies of ultrabasites that trace fragments of a deep-seated fault.

Listvenites formed after rocks of the volcanogenic-sedimentary sequence are characterized by the complete or partial replacement of the rock-forming minerals and volcanic glass by epidote, chlorite, calcite, ankerite, albite and, in part, sericite. Listvenites with a subparallel texture, containing xenomorphic grains of chlorite, epidote and calcite together with sericite flakes, are localized in fault zones; they typically carry disseminated pyrite and arsenopyrite. These represent transitional varieties between propylites and beresites.

Beresites are most widely developed in the southern and south-western parts of the area, being confined to tuffs of mafic and intermediate composition, sandstones, and carbonaceous silty argillites. Beresites typically consist

of quartz, sericite, muscovite and oxidized pyrite, with a variable content of veinlet segregations of chlorite, albite and carbonate (ankerite and siderite).

DISCUSSION

As is well known, unlike the genesis of the Kyzylkum gold deposits localized in carbonaceous-shale sequences, most researchers propose and substantiate an exclusively volcanogenic-hydrothermal origin for the mineralization at Balpantau. The principal evidence for this is the spatial coincidence of the mineralization with the periphery of the subvolcanic body (the Balpantau subvolcano), the density, quantity and quality of the mineralization decreasing with distance from the subvolcano.

Moreover, the principal type of near-ore alteration — listwaenitization and propylitization of the rocks — is likewise characteristic mainly of areas where mafic and intermediate volcanism is developed, and the metasomatites are more often established in spatial association with the subvolcanic edifice. At the same time, the rocks of the subvolcano are most strongly altered in their exocontact parts, i.e. at a considerable distance from the central parts of the body, suggesting that the tectonic contacts of the subvolcano with the host rocks served as the principal conduit for hydrothermal solutions, which penetrated a series of spallation fractures that developed extensively in the layered sedimentary-volcanogenic rocks during emplacement of the subvolcano. It follows that the formation of the metasomatites, and subsequently the process of ore deposition, were most probably close in time to the emplacement of the subvolcano.

The ore bodies of the area are cut by all the dykes [1]. According to one interpretation, the spatial arrangement of the dykes, and the structure hosting them, can be depicted as a semi-annular pattern around the subvolcano, which may accordingly be interpreted as a subsidence caldera formed upon cooling of the subvolcanic body, compensating for the loss of volume. Thus, the time of formation of the main part of the mineralization falls within the interval between the emplacement of the subvolcano and the emplacement of the dykes. A concluding quartz-carbonate-gold-silver stage is recorded on the dykes, manifested in their intense sericitization and carbonatization.

The most extensive occurrences of gold mineralization of economic significance are spatially confined to the intensely altered volcanogenic-sedimentary part of the section of the Middle Carboniferous andesite-basalt formation, and gravitate toward the near-contact parts of the subvolcanic andesite-basalt bodies. Unaltered varieties of andesites and andesite-basalts within subvolcanic bodies, sills, lava flows and clastolavas are not gold-bearing.

In the sedimentary-volcanogenic formations the degree of hydrothermal-metasomatic transformation is more extensive, with the thickness of the alteration zones reaching tens of metres; the rocks are intensely tectonized, sericitized, sulphidized and silicified. The sulphides are oxidized or partly oxidized, silicification is of veinlet type, and the veinlets are thicker and more extensive, as, correspondingly, is the intensity of the gold mineralization.

On the basis of the crosscutting of a gold-bearing quartz-arsenopyrite vein by a lamprophyre dyke, which is in turn overprinted by beresite alteration, A.T. Bendik [1] established the multi-episodic character of metasomatite formation in the Tamdybulak–Balpantau ore field. The results obtained in the present study allow us to note the multistage (but not multi-episodic) character of the processes of formation of near-ore alteration and gold mineralization in the Tamdybulak–Balpantau area: during the early stages a relatively high-temperature replacement of the volcanic rocks by amphibole took place, in association with a productive quartz-gold-arsenopyrite assemblage; this was followed by the emplacement of lamprophyre dykes of the South Tien Shan complex, upon which beresite-listvenite near-ore alterations with a quartz-carbonate-sulphide (gold- and silver-bearing) assemblage were superimposed. All the above-mentioned metasomatic alterations and gold-productive assemblages represent the manifestation of different stages of a single hydrothermal episode of mineral formation.

The mineral composition of the secondary metasomatic alteration depends on the composition of the primary rocks: near-ore alteration of mafic and ultramafic rocks produces amphiboles and epidote, whereas beresite-listvenite metasomatites form after intermediate volcanic rocks and the terrigenous component of the section.

CONCLUSIONS

The study of the metasomatic alteration of the rocks and its relationship with gold-ore mineralization has established that the earliest and highest-temperature process was intense actinolitization and epidotization, widely developed in basalts and andesite-basalts. This process may be assigned to the high-temperature actinolite-epidote facies. It was followed by metasomatites of epidote-chlorite-albite-carbonate composition, belonging to the propylitic formation of medium- to low-temperature metasomatic alteration. The quartz-sericite and quartz-carbonate-sericite metasomatic alterations with pyrite, which constitute the beresite-listvenite formations of near-ore alteration, have a distinctly cross-cutting, superimposed character and are confined mainly to fault zones and sub-concordant fault-tectonic structures.

The results of the study indicate the multistage character of the processes of near-ore alteration and gold mineralization formation in the Tamdybulak–Balpantau area; all of the metasomatic alterations and gold-productive assemblages noted above represent the consequence of different stages of a single hydrothermal episode of mineral formation.

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