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STRUCTURAL CONDITIONS FOR THE LOCALIZATION OF GOLD MINERALIZATION WITHIN THE TUTKHUN ORE FIELD (THE CENTRAL PART OF THE LESSER CAUCASUS)

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Summary. The gold-bearing areas of the ore field, the similarities and differences of the structural conditions of their formation, the elemental and mineral composition of the ores, various metasomatictes-propylites, beresites and, especially, secondary quartzites were studied.

Gold ore mineralization can be considered in terms of some regional features of the geological development of the Lesser Caucasus. The Upper Eocene intrusive and subvolcanic rocks represent a single complex that forms the Gazikhanli-Zargulu massif in the region, approaching the subvolcanic facies of magmatic rocks. The field of development of gold ore formations mainly covers outcrops of granitoid rocks of the massif and its exocontact aureoles, into which abundant dikes, the latest members of the Upper Eocene complex of intrusive formations, penetrate. The particularly close positional connection of gold ore mineralization with vein rocks cutting through all the massive and porphyry rocks of the massif indicates the control of this mineralization by the latest structural elements of the area, which occurred in the final period of the evolution of the Gazikhanli-Zargulu complex.

As can be seen, gold-bearing zones are paragenetically associated with dikes that complete the development of granitoid intrusive complexes. Both of them, which are closest in time to the development of magmatic and post-magmatic processes, use uniform structures of an earlier period of development in their localization.

Introduction

The epithermal Tutkhun ore field is located in the Kalbajar region and occupies part of the northern slope of the Mykhtokyan ridge in the upper reaches of the Tutkhun River (right large tributary of the Terter River). The tectonic structure of the ore field is determined by its location in the southwestern wing of the Saribaba trough within the Goycha-Akera structural-formational zone, which is associated with the development of the northeastern branch of the transregional Mesozoic Anatolian fault. Geological prospecting and exploration work in this area was carried out in the 60-70s of the last century and was accompanied by scientific research by researchers of the Institute of Geology and Geophysics of the National Academy of Sciences of Azerbaijan, Baku State University, CRGPI (Moscow), etc. A scientific database was formed in the course of the work, including numerous published works and production reports, the generalization and analysis of which made it possible to identify the main geological and genetic features of the ore field (Кашкай и др., 1967; Сулейманов, 1982 and etc.). This paper continues a series of publications concerning the structural features of ore localization and the structure of the ore field, ranging from the regional position to the characteristics of ore-bearing areas with different gold mineralization and resource potential (Баба-заде и др., 2003, 2023). The relevance of this paper is quite obvious, as since the publication of the monograph “Gold of Azerbaijan” in 2023 (Baba-zadeh V.M. and others), which collected materials of Azerbaijan researchers, a series of precision analytical studies that were previously inaccessible have been carried out. Despite the wide coverage of geological material and the novelty of the obtained data, while interpreting them, the abovementioned researchers did not take into account a number of works that could have resolved some controversial issues of the geological and genetic order. We will try to clarify these and other questions in this work that led to the formation of the Tutkhun field, and a large group of orogenic gold fields in the central part of the Lesser Caucasus.

Geological structure

The ore field, with an area of about 20 km^2, is composed of sedimentary and volcanogenic-sedimentary formations from the lower (Albian) and the upper structural stages (Cenomanian, Santonian, Campanian-Maastrichtian) of the Cretaceous to modern ones with numerous breaks, distinguished by the facies variation of the lithological composition of the rocks and the scale of effusive and intrusive magmatism (Fig.1). These rock complexes are accumulated in the linearly elongated Gazikhanli anticline in the northwestern direction, which is complicated by smaller faults that feather them and is accompanied by differently oriented zones of fracture intensity. Volcanogenic and sedimentary deposits of the Upper Cretaceous and individual bodies of syncollisional granitoids of the Tertiary intrusive complex breaking through them are exposed in the central part of the structure, beyond which the gold mineralization does not extend practically.

The duration of the geotectonic development of the Gazikhanli structure is evidenced by the occurrence of a thick series of intraformational conglomerates of the Cenomanian Age, which developed near this structure and extended along it. The abovementioned conglomerates contain gabbroids, granitoids, quartzites, jaspers, etc.

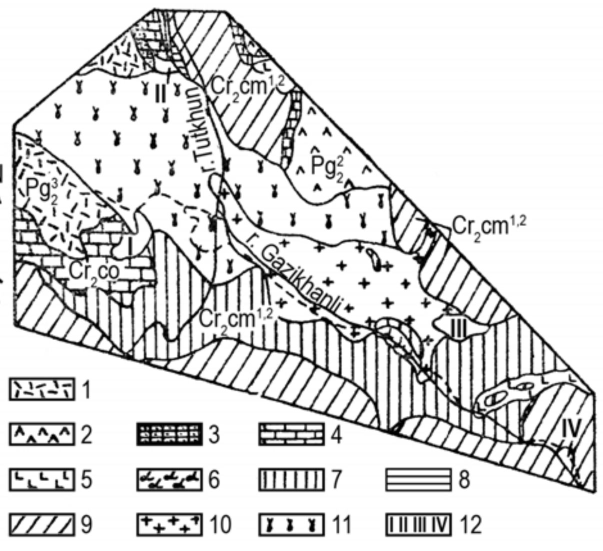

Fig. 1. Schematic geological map of the Tutkhun river basin (Compiled by A.I. Mammadov). 1 – The Upper Eocene-hydrothermally altered andesites and tuff breccias; 2 – the Middle Eocene tuffs and tuff sandstones; 3 – nummulitic limestones of the Middle Eocene; 4 – the Campanian-Maastrichtian stage-marly limestones; 5 – the Post-Santonian gabbroids; 6 – the Post-Santonian amphibolites; 7 – the Cenomanian stage-hornfels; 8 – epidosites; 9 – the Cenomanian stage-conglomerates, argillites, sandstones, lenses of limestones, tuff sandstones and gravelites; 10 – quartz diorite porphyry, adamellite porphyry and granodiorite porphyry (phase III); 11 – quartz and quartz-free diorites, tonalites, granodiorites (phase II); 12 – skarn areas: I – South Turkuchevan; II – North Turkuchevan; III – Gizilitan; IV – along the path from Turkuchevan village to Gazikhanli village

The Gazikhanli zone is limited by the Galaboynu from the southwest, and by the Boyukboz synclinal folds from the northeast, which also played a fairly active role in the formation of the Tutkhun gold ore field.

There are intrusive analogues of younger terrestrial formations within the anticline that are similar in age and petrographic composition, represented by a diverse series of igneous rocks. All of them are the Post-Cenomanian and, mainly the Post-Campanian (Кашкай и др., 1967).

The most ancient intrusive rocks are serpentinized and talcose ultrabasic rocks, confined to local anticlinal structures and intruded by small intrusive bodies of basic, intermediate and felsic composition.

The main mass of intrusive formations within the Tutkhun ore field consists of the Post-Upper Eocene subvolcanic and hypabyssal granitoid bodies of the Gazikhanli-Zargulu intrusive complex (Геология Азербайджана, 2005). Rocks of two intrusion phases take part in its structure (Баба-заде и др., 2003; Волков и др., 2021). Earlier gabbroids, gabbro-diorites, diorites and quartz diorites are developed along the periphery of the complex. There are several stocks of granodiorites and granites in the central part of the complex. All these formations break through the Albian-Cenomanian and Middle Eocene deposits, having a contact impact on them, transforming them metasomatically into sericite-hydromicaceous-quartz rocks. According to its shape, the intrusion refers to a large fractured pluton, elongated in the northwest direction (300-310º), along the Tutkhun River valley for 10 km with a width of 0.2-2 km. The massif has a laccolith-like shape and a thickness of 300-500 m in cross section (Баба-заде и др., 2003; Волков и др., 2021).

The latter is represented by bodies of different morphology and size. Different parts of the intrusive were formed at different stratigraphic levels. The largest Gazikhanli massif of granitoids breaks through terrigenous deposits of the Cenomanian and Early Senonian (the main part of the intrusion), the marginal parts – the Upper Senonian-Lower Paleogene carbonate-tuffaceous rocks. The central, most deeply eroded part of the Gazikhanli intrusion, was formed at a depth of about 750-800 m, and the peripheral parts, breaking through the deposits of the Upper Senonian and Lower Paleogene were formed at a depth of 350-400 m. The same formation depth is observed on the Zargulu intrusion. In addition to paleogological data (Баба-заде и др., 2003), the near-surface conditions for the formation of the marginal parts of the considered intrusion are confirmed by the presence of low-temperature contact minerals (epidote, zoisite, albite, actinolite, chlorite, etc.) and the predominant porphyry structure of the intrusive rocks. The second intrusive massif is located in the northwest of the previous one in Aghzibir. It breaks through the Cenomanian deposits and gabbroids of the first phase. Numerous apophyses in the form of dikes extend from the intrusion into the host rocks, as in the Gazikhanli massif. The main occurrences of gold mineralization (the Agzibir and Malinovaya Balka areas) are associated with the rocks of the intrusive massif.

The next outcrop of the granitoid intrusion in the Turkuchevan area in the lower course of the Gazikhanli River is hypsometrically located slightly below, due to which the erosion cutting into the granitoid body turned out to be deeper. Naturally, the occurrence of deep facies in the intrusive massif is holocrystalline syenite-diorites, quartz diorites, etc. Porphyritic varieties occur in the elevated areas of the relief, and the marginal facies of the massif are characterized by effusive rocks.

There is a thick zone of clarified, silicified and kaolinized rocks in the contact zone of the intrusion with the host rocks. According to E.S.Suleymanov (Сулейманов, 1982), the content of combined water is 0.7-1.0% in 53 analyzes taken from quartz diorites and granodiorites, the Gazikhanli-Zargulu igneous complex, which is characteristic of intrusive massifs that crystallized at a depth of about 1 km (Баба-заде и др., 2003). Most likely, the massif records one of the large early Tertiary faults, accompanied by regional structures of the area, in particular, with the axis of the abovementioned anticlinal fold, composed of chalk volcanic-sedimentary formations. Holocrystalline rocks, which are structurally homogeneous, mainly hornblende-biotite quartz diorites are found along the tectonic faults. Plutonic rocks of the intrusion are accompanied by their subvolcanic analogues (stocks of quartz-diorite porphyrites and quartz-monzonite porphyrites predominate) along the contacts with the host rocks and, probably, in the roof.

Later, steeply dipping dikes were formed, concentrated in the apical and marginal parts of the intrusive massifs, often in the host rocks, as well as subvolcanic rocks of the same complex, at the final stage of which gold-bearing areas of the Tutkhun ore field were formed. The dikes are close to plutonic and subvolcanic rocks in terms of mineral composition, emphasizing the comagmatic nature of all igneous formations of the complex, but they are close to rocks of the effusive facies in formation and structure. Most of them can be called intrusive andesites and trachyandesites. A structural connection has been shown between dikes that complete the development of granitoid intrusive complexes and gold veins (Абдуллаева, 2023; Абдуллаева, Новрузова, 2023; Баба-заде, Новрузова, 2023). Both use the same structures from an earlier period of development in their location.

Most of the dikes are pre-ore, oriented to northwest and host ore bodies or are intersected by them. Dikes become denser and structurally isolated dike fields occur near granitoid massifs or in the contours of the latter. The largest and longest dikes represent a system of predominant northeastern swarms (formations), traced at a distance of 1-2 km or more.

All intrusive rocks of the Tertiary age represent a single complex of comagmatic formations, also related apparently to the strata of the Eocene andesites and their tuffs, developed within adjacent synclinal structures.

The boundaries of the Tutkhun ore field are limited by the contours of a tectonic block, within which a system of intersecting sublatitudinal (northwestern), near-meridional and diagonal faults of a lower order is developed (Минерально-сырьевые ресурсы Азербайджана, 2005). The latter led to the occurrence of a series of elevated and downthrown blocks, causing the stepped-block structure of the considered area. Gold-bearing stockworks and compound veins are controlled by this fault system and consist of en echelon zones of veinlet-impregnated ores (Баба-заде и др., 2003). The largest is the regional ore-controlling Gazikhanli fault of the northwestern orientation, which represents a system of steeply dipping faults within which ore-bearing zones are located (Fig. 2).

The tectonic zone is accompanied by numerous intersecting faults of a lower order, bearing traces of active hydrothermal alteration in the body of the intrusion and in the host volcanic-sedimentary rocks (including ultrabasites and gabbroids).

According to geophysical data, the Tutkhun ore field is localized in the superintrusive zone of the Gazikhanli-Zargulu intrusive complex, which creates a dome structure and is characterized by an alternating, rugged magnetic field (Баба-заде и др., 2003; Волков и др., 2021).

Metasomatic alteration in host rocks

Hydrothermal and metasomatic alterations in the host rocks were widely occurred with the development of albite, epidote, biotite, actinolite, sericite, chlorite, carbonates, kaolinite, argillite, sulfides, etc. in the Tutkhun ore field. More intense hydrothermal and metasomatic alterations occurred in the footwall of gold-bearing zones, where the host rocks were completely replaced by the secondary minerals, i.e. converted into metasomatic rocks (Баба-заде и др., 2003; Абдуллаева, Новрузова, 2023; Баба-заде и др., 2020; Баба-заде и др., 2023; Кашкай и др., 1967; Минерально-сырьевые ресурсы Азербайджана, 2005; Li, Yang, 2022).

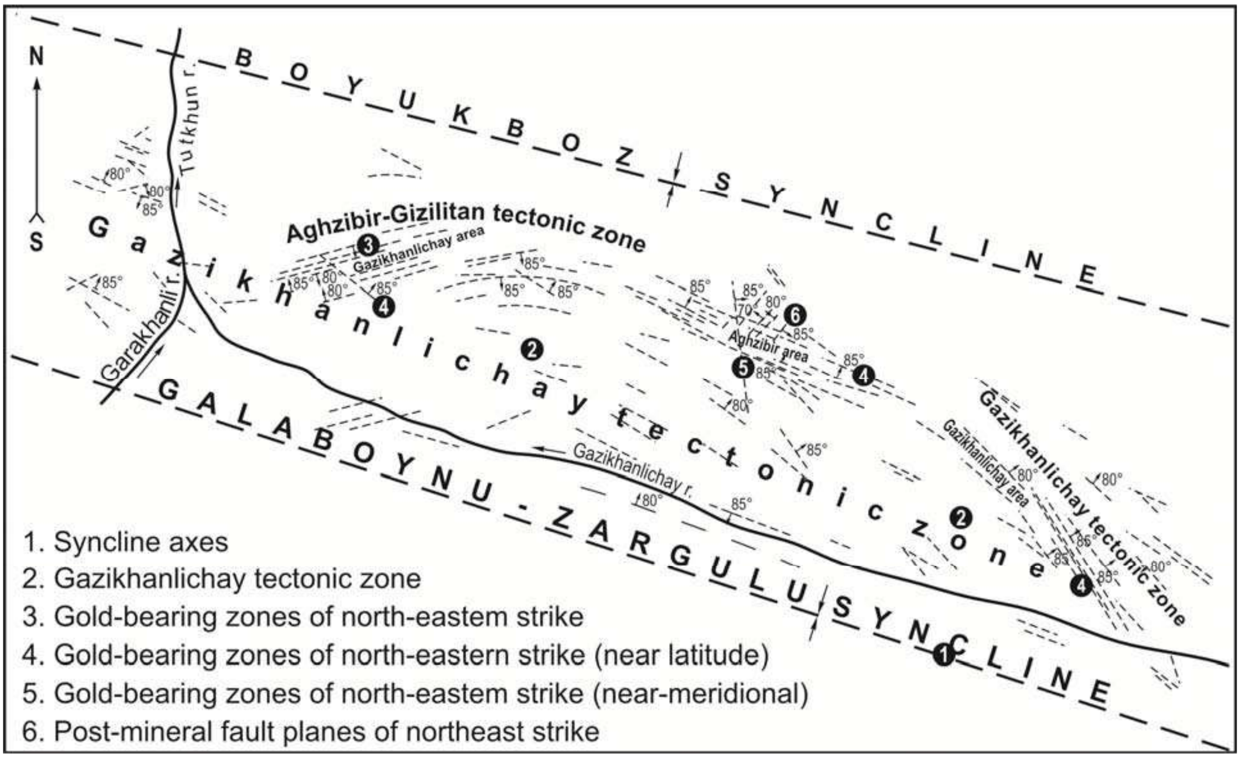

Fig. 2. Structural scheme of the Tutkhun ore field

Metasomatites in the direction from bottom to top and from the center of the field to its periphery are replaced by partially altered rocks. The outer zones correspond to higher temperature facies of propylites – albite-actinolite, albite-epidote-actinolite and biotite (weakly developed) developed mainly in the body of granitoids; the area of medium-temperature propylitization, reminiscent of listvenites (zones closest to the fracture cavity) with abundant pyrite, often with late quartz segregations, including hydromicas and adularia, is composed of mica-carbonate metasomatites – epidote-chlorite, kaolinite-sericite-quartz and sericite-chlorite-quartz varieties; the area of low-temperature propylitization facies consists of quartz-hydromica-kaolinite-carbonate formations with ferruginous carbonates, sulfides and subordinate alunite-group minerals, usually with veinlets and lenses of chalcedonic quartz and kaolinite. These new formations are observed at significantly lower hypsometric levels along fractures and zones of increased porosity and fracturing associated with faults, dike contacts, etc.

So, the structure of the altered rocks shows clearly vertical zoning, which allows them being considered in many ways similar to epithermal gold ore fields of the Tertiary formation.

Gold-bearing vein bodies occupy a definite position in this zonation, located on the border between metasomatites and partially altered rocks, i.e. zones, which are composed of sulfides, are mineral facies of the general aureole of hydrothermal and metasomatic alterations (Баба-заде и др., 2023; Абдуллаева, Новрузова, 2023; Баба-заде и др., 2003). The structure and composition of such zones correspond to areas of the ore field determined by the depth of development and does not occur together in all cases. The lowest temperature associations are better expressed at lower section levels and penetrate to a significant depth only along well-developed fracture zones. According to their composition, they show a noticeable difference in rocks of different initial compositions, approaching listvenites in rocks of a more basic composition, or kaolinite-hydromica beresites in rocks of a more acidic composition.

The formation of these halos covers predominantly the pre-ore (pre-productive) period of the formation of ore zones, but they are closely associated with the latest minerals of the early ore stage in their composition – nest-like and veinlet accumulations of coarse-grained quartz and scattered impregnations of coarse-crystalline pyrite, which experience distinct breaking and recrystallization in subsequent late stages.

Secondary quartzites occupy higher hypsometric elevations, developing due to granitoid intrusions (partially located in the endocontact zone) and effusive-pyroclastic rocks far from the intrusive outcrops (Баба-заде и др., 2023; Кашкай и др., 1967). Areal secondary quartzites are widely developed with numerous quartz, less quartz-carbonate vein-veinlet zones of northwestern strike, coinciding with the deep fault of the Gazikhanlichay tectonic zone.

Peculiarities of the Tutkhun ore field are the occurrence of pre-ore argillizated rocks, the presence of which allows us considering the field to be slightly eroded. Argillicites replace completely low-temperature propylites and hydromica alterations in the supra-ore gold-bearing zone, which are of a near-fracture nature.

Mineral composition of ores

According to the mineral composition, the fields of the ore field belong to the class of sulfide epithermal gold ores (Волков и др., 2018; 2021; Гордиенко и др., 2019; Кашкай и др., 1967; Некрасов, Дорожкина, 2020; Cong et al., 2023; Hlaing et al., 2021; Groves et al., 2020; Sillitoe et al., 2020). More than 50 minerals have been observed in the ores. At the same time, they are relatively simple in terms of the set of main minerals. The main ore minerals are pyrite (dominates sharply), chalcopyrite, sphalerite, galena, native gold, fahlores, and non-metallic are quartz, calcite, ankerite (Figs. 3-5). The ores contain small quantities of magnetite, molybdenite, tetrahedrite, boulangerite, jamesonite, bournonite, antimonite, orpiment, etc. The quantitative relationships between the main sulfide minerals remain quite stable, pyrite (more than 90%), chalcopyrite (5-8%) always predominant, and only in some cases chalcopyrite is inferior to sphalerite (2-5%). Galena (1-2%) is found in subordinate quantities in relation to sphalerite and pyrite, but almost always predominates over fahlores. Pyrite ores are characterized by an inequigranular texture, massive and brecciated textures.

Pyrites of gold ores in general, depending on the predominant development of faces in combinations, are classified into more than ten habitus. The highest frequency of occurrence is characterized by crystals of cubic, pentagonal dodecahedral and cube-pentagonal dodecahedral habitus (Коробейников и др., 1993). Research has shown (Кашкай и др., 1967) that the pyrites of the Tutkhun field have a zonal structure and emphasize the variability of crystal habitus during the growth process: early – pentagon-dodecahedral, late – cubic. Similar cases are observed in the Burgali epithermal gold field in Northeast Russia (Волков и др., 2021). Accumulation of aggregates of pyrite grains often have a round or oval shape with a concentrically zonal internal structure. Microthermometric studies of fluid inclusions in samples show that primary, primary-secondary and secondary inclusions are distinguished among them. A wide range of ore formation temperatures from 190°C to 240°C has been established (Баба-заде и др., 2003; Сулейманов, 1982). The highest temperature regime is characteristic of the initial (230ºC-240ºC), and the lowest (180ºC-200ºC) final stages of ore formation. These temperatures are close to the conditions for the formation of epithermal fields.

The available factual material allows assuming the occurrence of hydrothermal and metasomatic ore deposition, which is confirmed by clearly defined supra-ore hydrothermal halos, synchronous with ore formation.

The field has two productive stages of mineralization and mineral associations typical for them, separated by tectonic movements: I. Quartz-pyrite with a small amount of magnetite and molybdenite and milky white quartz. II. Main ore stage. The main ore stage is divided into 2 substages: 1) quartz-carbonate sulfide – quartz, carbonates (insignificantly), late pyrite, sulfides of lead, copper and zinc, tetrahedrite, silver, native gold were released in this substage; 2) quartz-carbonate-sulfoantimony substage, consisting mainly of fine-grained chalcedonic quartz and sulfides, sulfoantimonites, native gold, silver, which intersect the early generation quartz of the first stage in the form of small veinlets.

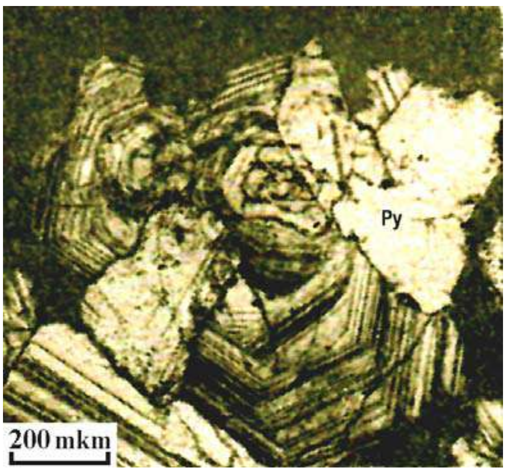

Fig. 3. Pyrite grains showing zonal structure after etching HCl+Zn dust. Etching revealed a small cataclasis in the pyrite grains. Gizilitan area

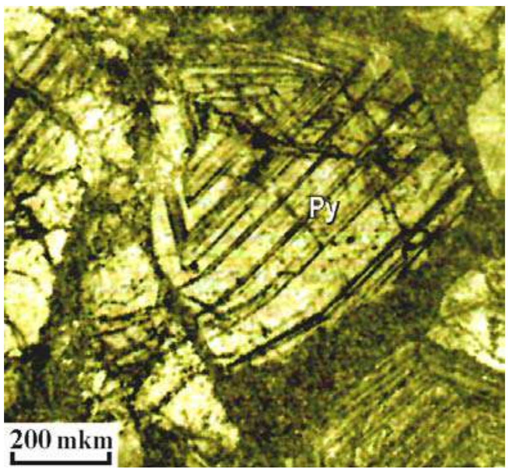

Fig. 4. Large zoned pyrite crystal. The pyrite grain (Py) of late generation grown on it. Etched with HCl+Zn dust. Gizilitan area

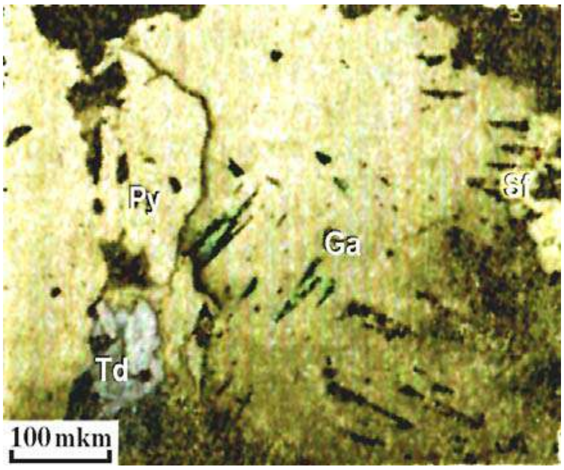

Fig. 5. Structural relationships of galena (Ga), pyrite (Py), white relief, sphalerite (Sf), dark gray and fahlore (Td). You can see how fahlore cements pyrite segregations in the lower left part of the figure. Ore vein on the Galaboynusu river

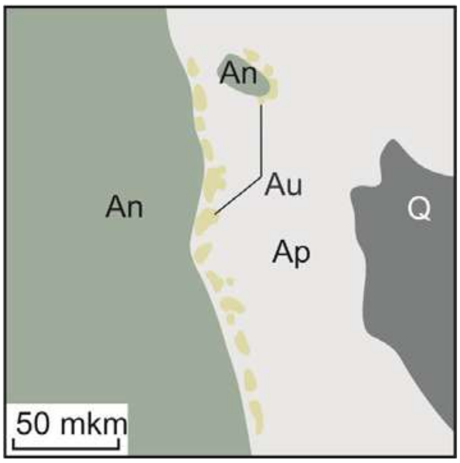

Fig. 6. Overgrowths and curved segregations of gold (Au) in association with orpiment (Ap) and antimonite (An) and quartz (Q). Aghzibir area

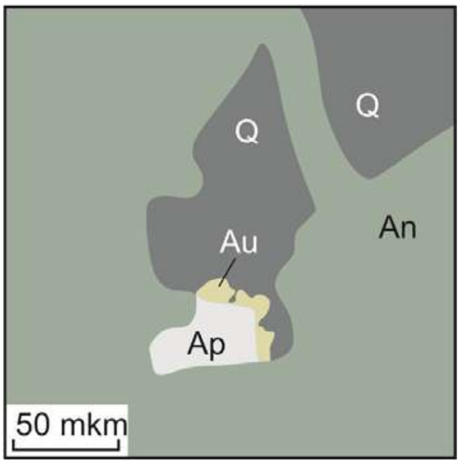

Fig. 7. Chain segregations of gold (Au) at the junctions of orpiment (Ap) and antimonite (An). The inclusion of quartz on the right (<3). Aghzibir area

Most of the gold of the first substage is dispersed in quartz, developing along the boundaries of euhedral crystals of the latter. Native gold of various gold fineness is found mainly in samples of quartz veins and zones, where sulfides and sulfosalts of copper and lead are visually observed, and microscopy also shows the occurrence of realgar and orpiment (Кашкай и др., 1967).

Besides native and finely dispersed gold, there is coarse dust-like gold, the occurrence of which is confirmed by spectral and chemical analysis data. Au is observed intergrown with antimonite, realgar and orpiment, and the largest number of grains of this metal is confined to areas of the zone where antimonite is in association with orpiment and realgar (Кашкай и др., 1967) (Figs. 6, 7). Sometimes, there are tiny inclusions of low-grade gold (300-350‰) with the addition of a small amount of Ag from fahlores, hessite in quartz (Баба-заде и др., 2003; Волков и др., 2018; 2021) which is rare (fine to dust-like 5-50 μm). Au grain sizes vary between 0.018-0.08 mm.

The relationship between Au and accompanying minerals shows the proximity in time of their precipitation from solutions, with some delay of gold, which allows placing them in the following series: antimonite → realgar → orpiment → gold (Кашкай и др., 1967). Silver, like gold, is characterized by uneven distribution. It is found in the form of its own minerals (native silver, hessite) and in the form of impurities. It was observed (V.Ramazanov, E.Suleymanov) in three minerals out of five subjected to local X-ray spectral analysis in the composition of freibergite, tetrahedrite and galena. The highest concentration corresponds to freibergite (16.18 wt.%). Silver follows generally gold in a multistage hydrothermal process, and forms higher concentrations in the middle and late stages of mineralization.

The quartz-carbonate ore-free third stage of mineralization is represented by quartz, calcite, and ankerite. Mineral associations of the third stage of the ore process in most cases are also clearly telescoped, forming independent systems of thin, almost irregular quartz-carbonate veinlets and veins, which cut the veinlets of ores of early stages clearly in all possible directions.

This alteration in mineral parageneses is also reflected in other epithermal gold ore fields of the Tertiary formation. At the same time, autonomous features are observed in the Tutkhun field that distinguish it from other epithermal gold ore fields of the Tertiary formation, in particular the Zod field, with which it is located in a single tectonic zone and, apparently, coincides in the time of formation. The most significant difference of the Zod field is the much clearer isolation of mineral associations of different stages. According to S.O.Amiryan (Амирян, 1984), mineral associations of different stages of the ore process of the Zod field form clearly independent veinlets, deposited in different conditions and differing in the textures and structures of the ores, which indicates very active intra-mineralization tectonic movements and heterogeneous changes in the regimes of the hydrothermal process (for example, the formation of independent stages of productive mineral associations – carbonate veinlets with native gold and cobalt and nickel diarsenides, or later native gold with silver and gold tellurides in the environment of little altered rocks, which are rich in bases – gabbro-peridotites). At the same time, mineral associations of different stages of the ore process are weakly telescoped and spatially closely combined in the gold ore zones of the Tutkhun field. Here, minerals such as pyrite, magnetite, chalcopyrite and sphalerite are observed in the parageneses of the early stages, which are also characteristic of the composition of the ores of the early stages of the Zod field. Typical minerals are sulfoantimonites (boulangerite, jamesonite, bournonite and antimonite in association with calcite and ankerite) in both fields in the associations of the latest stages. Besides low-grade native gold, there are chalcopyrite, fahlores-tetrahedrite in productive gold ore stages, however, they are accompanied by diarsenides of nickel, cobalt and tellurides of gold and silver at the Zod field, while these elements (Ag, Ni, Co, Te) have so far been observed only in a dispersed state in the ores of the Tutkhun field.

All mineral associations in the ores of the Tutkhun field, although with variable gold concentrations, are located in highly altered rocks of the most recent stages of acidic near-fracture metasomatism. Highly productive mineral associations with native gold and tellurides are usually localized in slightly altered bedrocks at the Zod field.

The field includes more than ten gold-bearing areas, 5 of which are of practical interest: Gazikhanli, Aghzibir, Gizil-Itan, Zargulu and Galaboynu. All of them are characterized by similar features of the geological structure, so below we will limit ourselves to a very brief description of *the Gazikhanli area*. The latter is located between the third and fourth tributaries of the Gazikhanli River on the northwestern flank of the eastern outlet of the Gazikhanli-Zargulu massif, which adjoins a steeply dipping ore-control fault here. There are frequent cases of alterations of its direction along strike and dip (Баба-заде и др., 2003; Геология Азербайджана, 2005; Минерально-сырьевые ресурсы Азербайджана, 2005; Сулейманов, 1984). The long-term development of the fault is determined by the position of the rocks of the main facies of the intrusion. It is also recorded by later dikes of several age series and even later gold-bearing zones of hydrothermally altered rocks, studied mainly from the surface and from drill-hole cores to depth. All these elements of the structure of the Gazikhanli area, including propylitized gold-bearing zones (more than 15), are dissected by quartz veinlets and veins of varying thickness (from 3-10 to 25-30 cm in places of swelling) and are developed along the pleural sutures of the fault with a predominant northwestern orientation and steep dip angles (Figs. 8-10). They are subparallel to the fault and the contacts (extensions) of the intrusive outcrop.

Hydrothematically altered gold-bearing zones are the main morphological type. Many of them have a sharply varying thickness from 10-20 cm to 1.5-2 m (average 0.4-0.5 m) along their strike and therefore have winding outlines. The length of zones is up to 500 m and more. The distance between zones is 10-50 m. Gold-bearing quartz veins are less common and are confined to shear fractures in the bodies of granitoid massifs. Their length is 100-200 m, only in some cases their length reaches 400-500 m. Veins with a thickness of 15-20 cm predominate. Most of them have a simple structure, but there are complex bodies of filling, caused by the extension of veins in their thickness, extent and dip, due to repeated reopening of fractures and filling them with new portions of hydrothermal vents.

Stockworks of variable thickness, which are represented by veins and veinlets, are associated with fracture zones and are being developed in the Gazikhanli and Aghzibir areas. The fractures are conducted with quartz-carbonate material and are accompanied by pyrite, chalcopyrite, galena, sphalerite, antimonite, realgar, fahlores, molybdenite and native gold. There are rich accumulations of pyrite, molybdenite, fahlores, etc. in individual quartz veins (Gizil-Itan area). Veins with a quartz-carbonate aggregate are occasionally found in the gold-bearing belt, where there is approximately the same amount of carbonates (calcite, dolomite) as quartz. Mineralization is characterized by a rich content of sulfides (10-15 %), oxides, hydroxides, etc.

The distribution of gold and silver in gold-bearing zones and veins is extremely uneven.

Genetically, the zones are younger than the dikes and cut them. Their thickness often decreases to 0.1 m and the quartz disappears in dikes. According to exploration data, the length of the zones is up to 800 m, their thickness varies from several tens of cm to 3 m or more in the central part. The vertical range of mineralization is up to 300 m. The gold-bearing zones of the Gazikhanli area, like other areas, are characterized by branching along strike. Au content from "mark" up to 5.2 g/t, with the maximum gold content concentrated in selvages.

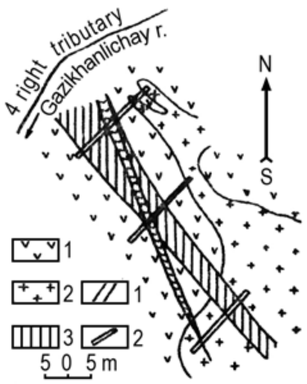

Fig. 8. Relationship between porphyrites (1), granitoids (2), hornblende diorite porphyrite dike (3) and the gold-bearing zone in the northwestern direction (4). The left slope of the fourth right tributary of the Gazikhanli river

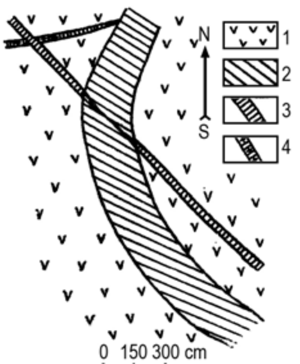

Fig. 9. Age relationship between a diorite porphyrite dike and two mineralized fractures of different directions. Gazikhanli area. 1 – porphyrites; 2 – dike; 3 – gold-bearing zone in NW direction; 4 – galenite-bearing zone in NE direction

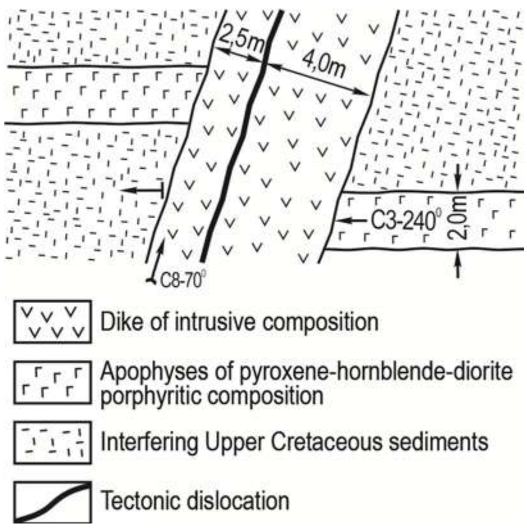

Fig. 10. Displacement by a dike of intrusive andesites of a vein apophyses of pyroxene-hornblende-diorite of porphyritic composition (sketch of an outcrop at the junction of the Gazikhanli and Tutkhun rivers)

Sulfides form abundant impregnation in quartz. They are represented by pyrite, less chalcopyrite, sphalerite and galena. Sulfoantimonites, fahlores and other minerals are observed in a number of zones. Magnetite, molybdenite, hematite, arsenopyrite, scheelite, chalcopyrite and malachite were observed in the crushed sample.

Physical and mechanical properties of rocks

The study of the physical and mechanical properties of rocks shows that the intensity of deformation of rocks, besides their chemical composition, was of decisive importance for the course of hydrothermal processes and the spatial distribution of their occurrences, including occurrences of gold mineralization, causing its predominant concentration in individual rocks. In this aspect, the interaction zone of the Gazikhanli-Zargulu intrusive complex, which is saturated with the latest dikes and sills, was a particularly permeable and favorable environment for ore deposition. Earlier generations of pyroxene-hornblende porphyrite dikes in each area, as well as massive granitoid rocks and host porphyrites are intersected by ore zones in the same direction in which later generations of dikes intersect them.

So, the later generations of dikes (intrusive andesites, intrusive dacites, granodiorite porphyries) created the mechanical heterogeneity (anisotropy) of the environment, thereby predetermining the main direction of the ore zones. The influence of such dikes on the formation of ore zones was associated not only with their position in the structure, but also with their physical and mechanical properties. As the most recent formations, they experienced the least deformation relative to all host rocks, including dikes of earlier generations.

Thus representing a rigid framework in the structures of gold-bearing areas, late dikes determined the greatest possibility of fracture opening, which are parallel to them along the strike. Ore solutions were used by these fractures at all subsequent stages of the ore process. The movement of solutions along such fractures and the widespread metasomatism of rocks along them were facilitated by the higher porosity (and correspondingly less volume and weight) of all rocks of the host dyke of the latest generation.

The results presented in Table 1 and Fig. 11 do not take into account or take into account very insufficiently the dependence of the strength properties of various types of rocks on confining pressure, temperature, the degree of previous deformation, on the duration of stress and other factors that determine one or another deformation mechanism. However, even in approximate form, these data illustrate the conclusions on the predominant localization of gold mineralization in certain zones and the dependence of the nature of deformation and its intensity on the primary petrographic features of certain formations.

The mineralized zones develop well in tuffaceous rocks, which are characterized by intense dislocation, fragility and significant porosity. The thickness of the zones decreases sharply with the transition to denser rocks (granitoids), and they branch into a number of small, rapidly cropping out veins and veinlets.

The presence of tectonic structures, hypabyssal and subvolcanic bodies and contacts between lithologically contrasting formations is also of great importance for increasing the deformation of certain parts of the ore field.

All these features determined the physical and mechanical heterogeneity of the environment subjected to deformation and the maximum concentration of tectonic fractures in certain areas and rocks. The intensity of rock deformation, besides their chemical composition, was of decisive importance for the course of hydrothermal processes and the spatial distribution of their occurrence, including occurrences of gold mineralization, determining its predominant concentration in certain zones occupying a certain stratigraphic position in the section of the ore field (Groves et al., 2020, Li, Yang, 2022).

Table 1

Table to determine the effective porosity of rock samples taken from the Tutkhun ore field
(laboratory of IGEM RAS, analyst B.P.Belikov)

Rock names	Volume weight	Effective porosity, %
Hornfelsed rock	2.95	0.35
Dyke of intrusive dacite	2.95	0.68
Dyke of intrusive dacite	2.64	1.21
Dyke of plagioclase-quartz porphyrite	2.65	1.27
Dyke of intrusive dacite	2.67	1.34
Dyke of plagioclase-quartz porphyrite	2.69	1.40
Dyke of intrusive andesite	2.61	1.59
Hornblende quartz diorite-banatite (massif)	2.68	2.17
Altered porphyrite (host rock)	2.69	2.58
Quartz diorite-banatite	2.66	2.95
Andesite-dacite lavas	2.61	3.00
Quartz monzonite porphyry	2.56	3.53
Quartz monzonite porphyry	2.63	4.08

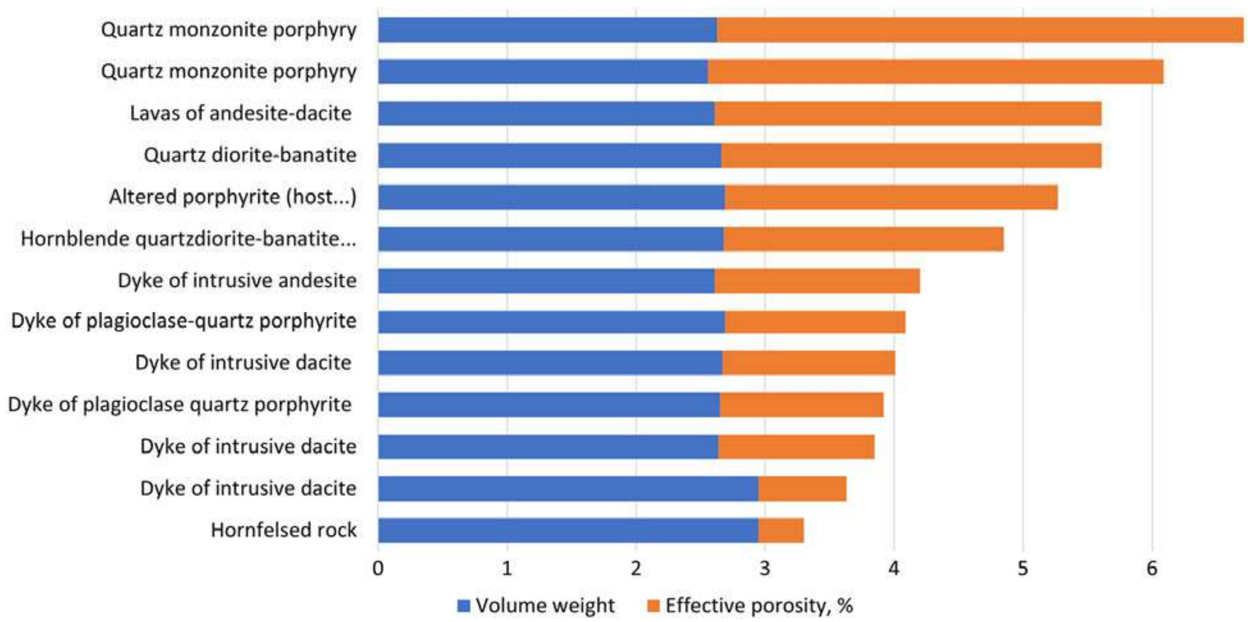

Fig. 11. Petrographic composition of the studied rock samples taken from the Tutkhun ore field

Petrochemical characteristics of rocks of the Tertiary intrusive complex

Analysis of the petrographic features, which are developed in the Tutkhun ore field of igneous complexes and the conditions of their spatial distribution allow drawing a number of conclusions on the evolution of magmatism in Tertiary times, on the relationships between the types of igneous rocks, which is important for elucidating the patterns of distribution of gold mineralization in space. Igneous rocks are distinguished by certain petrochemical characteristics. Tables 2, 3 and Figure 12 give every reason to consider all the characterized rocks of the Tertiary intrusive complex as a single family of rocks associated with the differentiation of the original diorite (andesite) magma. According to the data in the diagram, some phases of this intrusive complex differ little in their petrochemical features. At the same time, the rocks of the complex with a similar bulk composition differ significantly due to the different facial position of the rocks.

So, the above-mentioned rocks, although they represent independent intrusive facies, belong undoubtedly to a single comagmatic series with similar typomorphic features of the rock-forming minerals and are associated with general chemical features. The compiled diagram allows combining them into a single complex corresponding to a series of calc-sodium rocks, which are saturated moderately with silica.

The following facts, which have obviously important petrological significance, attract attention with all the diversity of igneous rocks of the Tertiary intrusive complex.

1. The intrusive rocks of the massif are distinguished by a slight excess of alumina, of which the early phase of subvolcanic rocks such as quartz diorites and monzonite porphyrites are characterized by slightly increased alkalinity. Subsequent phases of vein rocks are distinguished by an excess of lime, not counting extremely propylitized rock varieties, in which a relative excess of alumina is associated with superimposed processes.

2. The earlier series of porphyrite dikes are enriched in bases, and the latest series of quartz plagioporphyrite dikes (porphyry granodiorite) is significantly more acidic than all the preceding rocks of the intrusive complex. This course of melt differentiation explains easily the accumulation in residual melts, together with volatile bases, which are associated with subsequent magmatic carbonatization, chloritization and epidotization of all members of the intrusive series, as well as the host strata of Cretaceous porphyrites where these rocks were subjected to tectonic disturbances.

3. Rocks of the subvolcanic facies and the earliest dykes of pyroxene-hornblende diorite porphyrites, which are closely related to them, belong to the group of moderately saturated silica and alkalis, with a significant predominance of sodium, as well as mesocratic types. They are closest to the average type of quartz monzonite. Data from recalculation of chemical analyzes of rocks of the plutonic facies of the intrusion, as well as their structures and mineral composition, indicate that they belong to the soda-calcareous series of rocks of the diorite family, which somewhat oversaturated with silica and relatively poor in alkalis, very close to the average composition of quartz diorites.

4. The alkali content is relatively low and moderate with a sharp predominance of sodium. Unlike plutonic analogues (quartz diorites), the vein series of the first three generations show some deficiency of alumina, despite clear signs of secondary alteration, usually leading to a relative accumulation of alumina. Such accumulation is observed only for extremely propylitized varieties.

5. Finally, the most significant feature of the chemistry of the latest series of vein rocks is the sharply increased amount of silica and alkalis, with a simultaneous increase in the role of potassium, although still with a relative predominance of sodium. The numerical characteristics of rocks of this type are closest to the average type of dacite.

Conclusion

The Tutkhun gold epithermal ore field is a fairly large object in the central part of the Lesser Caucasus (Баба-заде и др., 2020; Минерально-сырьевые ресурсы Азербайджана, 2005). Analysis of the geological and structural features of the ore field showed that the presence of a regional steeply dipping fault of the northwestern strike, which are accompanied by numerous parallel and feathering fractures, can serve as an important predictive and prospecting criterion, indicating the possibility of discovering a similar type of epithermal gold ore fields, including those not exposed to the surface. It has been established that the Tutkhun field is very similar to other epithermal gold fields in the region, in particular Zod (Амирян, 1984). Two successively formed gold-bearing mineral associations have been observed: quartz-carbonate sulfide and quartz-carbonate-sulfoantimonite, separated by tectonic movements. It should be noted that the ores of the Tutkhun and Zod fields are similar in the occurrence in productive associations of late stages of sulfoantimonites (boulangerite, jamesonite, bournonite and antimonite), the occurrence of chalcopyrite, fahlores, similar temperature conditions of ore formation, etc. The studies made it possible to establish that dikes and ore-bearing zones often fill the same tectonic fractures.

Table 2

Chemical composition of igneous rocks of the Tertiary intrusive complex of the Tutkhun ore field

№	1	8	26	39	2	506	558	227	552	557	6	7	13	14	32
SiO_2	60.01	57.29	59.28	63.84	61.11	64.01	62.27	53.89	51.86	57.15	55.67	56.78	53.78	59.23	66.03
TiO_2	0.02	0.04	0.05	0.05	0.01	0.07	0.05	0.60	0.12	0.07	0.01	0.01	0.02	0.02	0.03
Fe_2O_3	6.14	5.63	5.22	4.48	4.60	6.32	5.18	6.16	5.84	6.12	5.79	5.36	5.80	7.10	4.02
Al_2O_3	19.84	20.76	18.13	18.39	16.99	16.11	17.17	19.36	20.90	18.75	18.77	18.17	20.26	17.28	17.03
Na_2O	5.28	5.46	4.14	3.28	5.56	5.13	4.62	4.39	6.59	4.74	4.64	4.74	3.74	4.57	3.77
K_2O	0.45	0.44	0.36	0.17	0.57	1.32	0.13	1.04	1.33	1.33			0.30	0.21	1.96
MnO		0.03	0.16	0.04								0.17	0.17	0.01	
CaO	7.06	5.04	6.08	6.14	2.0	3.02	2.86	6.06	4.86	5.74	6.70	7.00	6.82	5.63	5.10
MgO	0.20	3.28	2.10	2.12	3.06	2.50	0.62	4.58	3.02	3.38	4.10	3.06	3.16	1.82	0.39
SO_3				0.20	2.06	0.58	3.92	0.36		1.30		0.78			
H_2O	0.19	0.29	0.36	0.30	0.35		0.39	0.39	0.39	0.46	0.59	0.10	0.88	0.38	0.49
LOI	1.35	1.67	3.28	1.00	3.94	1.28	3.27	4.01	5.40	1.47	3.65	3.76	5.28	4.65	1.54
∑	100.54	99.98	94.75	99.36	100.2	100.34	100.48	100.34	100.31	100.39	99.91	100.48	100.17	100.43	100.36
		Hornblende-biotite quartz diorites, banatites (plutonic facies of the massif)		Dikes of pyroxene-hornblende-diorite porphyrite		Quartz-diorite (monzonite) porphyrites, subvolcanic facies of the massif		Dikes of pyroxene hornblende (diabase) porphyrite		Plagioclase hornblende porphyrites (intrusive andesites and trachyandesites)		Plagioclase quartz porphyrites		Quartz plagioporphyries (intrusive dacites and granodiorite porphyries)	

Table 3

Numerical characteristics of rocks of the Tertiary intrusive complex of the Tutkhun ore field

№	1	8	26	39	2	506	558	227	552	557	6	7	13	14	32
a	15.1	13.6	10.4	7.6	13.6	13.1	10.6	12	18.6	12.8	10.9	10.9	9.7	9.3	11.6
c	8.9	2.4	7.9	7.7	2.4	3.6	3.7	7.9	6.3	6.3	7.9	7.3	9.1	6.9	6
b	8.9	12.7	9.8	9.9	12.7	10.6	11.7	14.1	11.1	12.1	13.4	14.2	13.6	16.1	4.7
s	67.1	71.3	71.9	74.8	71.3	78.7	74	66	64	68.8	67.8	67.6	67.4	67.4	77.7
c'	22.1	–	1.6	–	–	–	–	0	1.4	4.3	6	11.2	–	–	9.1
d'	–	26.4	–	22.7	26.4	10.3	50.9	–	–	–	–	–	15.9	0.9	–
f'	73.1	31.8	55	39.7	31.8	50	40	40.6	48.5	45.2	39.6	34.7	39.8	18.4	74.8
m'	4.8	41.8	43.4	37.6	41.8	39.7	9.1	59.4	50.1	50.5	54.4	53.6	44.8	80.7	16.1
n'	94.4	92.5	94.5	96.6	92.5	85.5	96.9	86.5	88.3	84.4	100	100	95.3	96	74.4
afc	1.7	5.8	1.3	1	5.8	3.6	2.9	1.6	3	8.1	1.4	1.4	1.1	1.3	2
Q	4.9	1.3	15.1	26.7	13	15.6	23.1	0.4	15.5	55	4.1	6.1	6.5	9.6	26.2
	Hornblende-biotite quartz diorites, banatites (plutonic facies of the massif)				Dikes of pyroxene-hornblende diorite porphyrite	Quartz-diorite (monzonite) porphyrites, sub-volcanic facies of the massif		Dikes of pyroxene hornblende (diabase) porphyrite	Plagioclase hornblende porphyrites (intrusive andesites and trachyandesites)		Plagioclase quartz porphyrites				Quartz plagioporphyries (intrusive dacites and granodiorite porphyries)

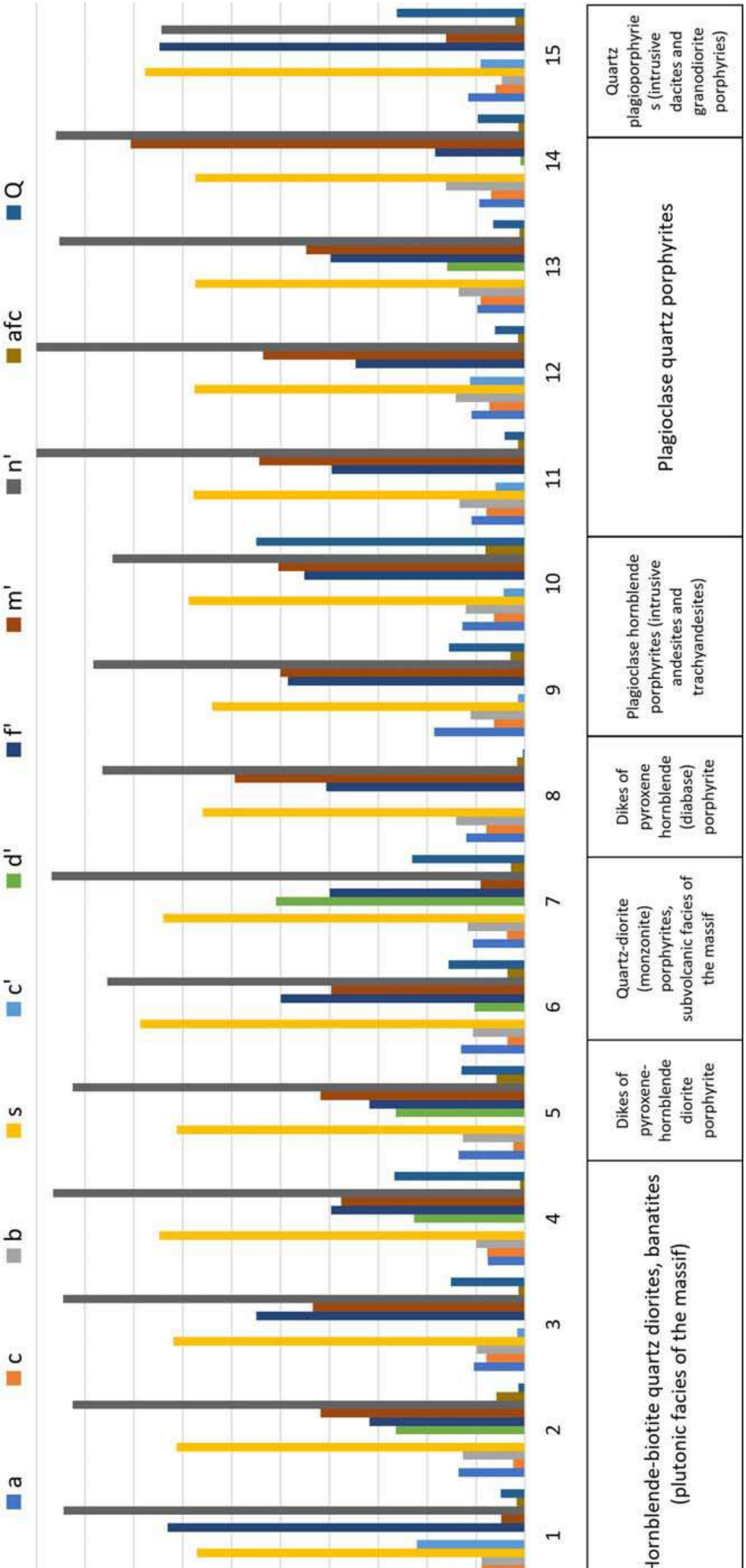

Fig. 12. Petrochemical diagram of rocks of the Tertiary intrusive complex of the Tutkhun ore field

At the same time, the mineralized zones clearly intersect and often displace the most ancient, and in some places, young dikes. So, late dikes created the mechanical heterogeneity of the environment, which predetermined the main directions of ore-bearing zones. At the same time, the dikes experienced the greatest hydrothermal alteration and contain a large amount of epigenetic minerals (carbonate, sericite, sulfides, kaolinite, chlorite, dispersed gold), similar to minerals of ore-bearing zones.

Elements of the internal structure of the mineralized zones, their morphology, thickness and ultimately, their gold mineralization are determined by the following structural and lithological features: impermeable barriers, boundaries of lithological strata, bends of ore-bearing zones, intense fracturing of ore-bearing rocks, especially between adjacent and parallel dikes, and others.

Ore-bearing zones of hydrothermally altered rocks are placed on all members of the intrusive complex, including the latest dykes. At the same time, comparative data on the content of dispersed gold in rocks of the Gazikhanli-Zargulu granitoid massif and its vein rocks that differ in the time of formation show that gold accumulates in the rocks of more and more recent intrusive members along with an increase in the content of volatile components in the same rocks (sulfuric anhydride, carbon dioxide and water).

REFERENCES

Abdullayeva Sh.F. The triune ore-concentrating structure – the junctions of large deep faults that control the placement of gold ore fields in the central part of the Lesser Caucasus. Materials of the Republican Scientific Conference. Baku, May 2-3, 2023 (in Russian).

Abdullayeva Sh.F., Novruzova S.R. Gold ore epithermal Tutkhun ore field (the central part of the Lesser Caucasus): geological aspects, structure, mineralogical and geochemical features, conditions of ore formation. Materials of the Republican Scientific Conference. Baku, 2023, pp.23-24 (in Russian).

Amiryan S.O. Gold formations of the Armenian SSR. Publishing House of the Academy of Sciences of the Armenian SSR. Yerevan, 1984, 303 p. (in Russian).

Baba-zadeh V.M., Kekelia S.A., Abdullayeva Sh.F., Kekelia M.A. Main features of the metallogeny of the Caucasus. Nedra. Moscow, 2020, 187 p. (in Russian).

Baba-zadeh V.M., Musayev Sh.D., Nasibov T.N., Ramazanov V.G. Gold of Azerbaijan. Azerbaijan National Encyclopedia. Baku, 2003, 424 p. (in Russian).

Baba-zadeh V.M., Novruzova S.R. On the relationship between hydrothermally altered rocks and mineralization at the main gold fields of Azerbaijan (Tutkhun ore field). News of Baku University (Series of natural sciences). 2023, No. 1, pp. 42-57 (in Russian).

Cong D., Yuan F., Pan T. et al. Genesis of the Heihaibei gold deposit in the East Kunlun Orogenic Belt, China: Evidence from in situ trace elements of gold-bearing sulfides and stable isotopes. Ore Geology Reviews, Jun., Vol. 157, 2023, pp. 105431-1-16.

Geology of Azerbaijan (ed. Ali-Zadeh Ak.A.). Vol. III. Magmatism. Nafta-Press. Baku, 2005, 434 p. (in Russian).

Geology of Azerbaijan (ed. Ali-Zadeh Ak.A.). Vol. IV. Tectonics (Goycha-Akera zone). Baku, Nafta-Press. 2005, pp. 262-317 (in Russian).

Geology of Azerbaijan (ed. Ali-Zadeh Ak.A.). Vol. VI. Minerals (Gold fields of the NE and central part of the Lesser Caucasus. Nafta-Press. Baku, 2005, pp. 236-272 (in Russian).

Gordienko I.V., Badmatsirenova R.A., Lantseva V.S., etc. Selenga ore region of Western Transbaikalia: structural and mineragenic zoning, genetic types of fields and geodynamic conditions of their formation. Geology of ore deposits, 2019, V. 61, No 5. pp. 3-36 (in Russian).

Groves D.I., Santosh M., Zhang L. A scale-integrated exploration model for orogenic gold deposits based on a mineral system approach. Geoscience Frontiers, Vol. 11, No. 3, 2020, pp. 719-738, DOI:10.1016/j.gsf.2019.12.007.

ЛИТЕРАТУРА

Абдуллаева Ш.Ф. Триединая рудоконцентрирующая структура – узлы сопряжения крупных глубинных разломов, контролирующих размещение золоторудных месторождений центральной части Малого Кавказа. Материалы республиканской научной конференции. Баку, 2-3 мая 2023.

Абдуллаева Ш.Ф., Новрузова С.Р. Золоторудное эпитермальное Тутхунское рудное поле (центральная часть Малого Кавказа): геологическое строение, структура, минералого-геохимические особенности, условия рудообразования. Материалы республиканской научной конференции. Баку, 2023, с.23-24.

Амирян Ш.О. Золоторудные формации Армянской ССР. Изд-во АН Арм.ССР. Ереван, 1984, 303 с.

Баба-заде В.М., Мусаев Ш.Д., Насибов Т.Н., Рамазанов В.Г. Золото Азербайджана. Азербайджан Милли Энсиклопедиясы. Баку, 2003. 424 с.

Баба-заде В.М., Кекелия С.А., Абдуллаева Ш.Ф., Кекелия М.А. Основные черты металлогении Кавказа. Недра. Москва, 2020, 187 с.

Баба-заде В.М., Новрузова С.Р. О соотношении гидротермально измененных пород и оруденения на главнейших золоторудных месторождениях Азербайджана (Тутхунское рудное поле). Вестник Бакинского Университета (серия естественных наук), No. 1, 2023, с. 42-57.

Волков А.В., Савва Н.Е., Колова Е.Е. и др. Au-Ag эпитермальное месторождение Двойное (п-ов Чукотка, Россия). Геология рудных месторождений, Т.60, No. 6, 2018, с. 590-609.

Волков А.В., Савва Н.Е., Ишков Б.И. и др. Эпитермальное Au-Ag месторождение Бургали в палеозойском Кедонском вулканическом поясе (Северо-Восток России). Геология рудных месторождений, Т. 63, No. 1, 2021, с. 40-61.

Геология Азербайджана (под ред. Али-Заде Ак.А.). Т.III. Магматизм. Nafta-Press. Баку, 2005, 434 с.

Геология Азербайджана (под ред. Али-Заде Ак.А.). Т.IV. Тектоника (Гейча-Акеринская зона). Nafta-Press. Баку, 2005, с. 262-317.

Геология Азербайджана (под ред. Али-Заде Ак.А.). Т.VI. Полезные ископаемые (Золоторудные месторождения СВ и центральной части Малого Кавказа). Nafta-Press. Баку, 2005, с. 236-272.

Гордиенко И.В., Бадмацыренова Р.А., Ланцева В.С. и др. Селенгинский рудный район Западного Забайкалья: структурно-минерагеническое районирование, генетические типы месторождений и геодинамические условия их образования. Геология рудных месторождений, 2019, Т. 61, No. 5, с. 3-36.

Hlaing M.K., Yonezu K., Zaw Kh. et al. Origin and characteristics of the Shwetagun Deposit, Modi Taung-Nankwe Gold District and the Kunzeik and Zibyaung Deposits, Kyaikhto Gold District in Mergui Belt, Myanmar: Implications for fluid source and orogenic gold mineralization. Frontiers in Earth Science, Vol. 9, 2021, pp. 772083-1-24, https://doi.org/10.3389/feart.2021.772083.

Kashkai M.A., Aliyev V.I., Mammamdov A.I., etc. Petrology and metallogeny of igneous rocks of the Tutkhun River basin. Publishing House of the Academy of Sciences of the Azerbaijan SSR. Baku, 1967, 207 p. (in Russian).

Korobeinikov A.F., Narseyev V.A., Pshenichkin A.Ya. et al. Pyrites of gold ore fields (properties, zoning, practical use). TsNIGRI. Moskva, 1993, 213 p. (in Russian).

Li H., Yang L. Alteration and mineralization patterns in orogenic gold deposits: Constraints from deposit observation and thermodynamic modeling. Chemical Geology, Vol. 607, No. 4, 2022 Sep., p. 121012.

Mineral resources of Azerbaijan (chief editor: V.M. Babazadeh). Azerbaijan National Encyclopedia. Baku, 2005, 808 p. (in Russian).

Nekrasov E.M., Dorozhkina L.A. Sukholozhskoe gold ore field and possible searches for ores on its flanks. Proceedings of higher educational institutions. Geology and exploration. Vol. 63(2), 2020, p. 21-34 (in Russian), https://doi.org/10.32454/0016-7762-2020-63-2-21-34.

Sillitoe R.H., Goldfarb R.J., Robert. F. et al. Geology of the world's major gold deposits and provinces [Special publications of the society of economic geologists]. Vol. 23, 2020, 845 p., https://doi.org/10.5382/SP.23.

Suleymanov E.S. Gold ore formations of the Lesser Caucasus. Elm. Baku, 1982, 280 p. (in Russian).

Volkov A.V., Savva N.E., Ishkov B.I. et al. Burgali epithermal Au-Ag field in the Paleozoic Kedon volcanic belt (North-East Russia). Geology of ore deposits, V. 63, No. 1, 2021, pp. 40-61 (in Russian).

Volkov A.V., Savva N.E., Kolova E.E. et al. Dvoinoye Au-Ag epithermal field (Chukotka Peninsula, Russia). Geology of ore fields, 2018, V.60, No. 6. pp. 590-609 (in Russian).

Коробейников А.Ф., Нарсеев В.А., Пшеничкин А.Я. и др. Пириты золоторудных месторождений (свойства, зональность, практическое применение). ЦНИГРИ. Москва, 1993, 213 с.

Кашкай М.А., Алиев В.И., Мамедов А.И. и др. Петрология и металлогения магматических пород бассейна реки Тутхун. Изд-во АН Азерб.ССР. Баку, 1967, 207 с.

Минерально-сырьевые ресурсы Азербайджана (под ред. В.М. Баба-заде). Азербайджан Милли Энсиклопедиясы. Баку, 2005, 808 с.

Некрасов Е.М., Дорожкина Л.А. Сухоложское золоторудное месторождение и возможные поиски руд на его флангах. Известия высших учебных заведений. Геология и разведка, Том 63(2), 2020, с. 21-34, https://doi.org/10.32454/0016-7762-2020-63-2-21-34.

Сулейманов Э.С. Золоторудные формации Малого Кавказа. Элм. Баку, 1982, 280 с.

Cong D., Yuan F., Pan T. et al. Genesis of the Heihaibei gold deposit in the East Kunlun Orogenic Belt, China: Evidence from in situ trace elements of gold-bearing sulfides and stable isotopes. Ore Geology Reviews, Jun., Vol. 157, 2023, pp. 105431-1-16.

Hlaing M.K., Yonezu K., Zaw Kh. et al. Origin and characteristics of the Shwetagun Deposit, Modi Taung-Nankwe Gold District and the Kunzeik and Zibyaung Deposits, Kyaikhto Gold District in Mergui Belt, Myanmar: Implications for fluid source and orogenic gold mineralization. Frontiers in Earth Science, Vol. 9, 2021, pp. 772083-1-24, https://doi.org/10.3389/feart.2021.772083.

Groves D.I., Santosh M., Zhang L. A scale-integrated exploration model for orogenic gold deposits based on a mineral system approach. Geoscience Frontiers, Vol. 11, No. 3, 2020, pp. 719-738, DOI:10.1016/j.gsf.2019.12.007.

Li H., Yang L. Alteration and mineralization patterns in orogenic gold deposits: Constraints from deposit observation and thermodynamic modeling. Chemical Geology, Vol. 607, No. 4, 2022 Sep., p. 121012.

Sillitoe R.H., Goldfarb R.J., Robert. F. et al. Geology of the world's major gold deposits and provinces [Special publications of the society of economic geologists]. Vol. 23, 2020, 845 p., https://doi.org/10.5382/SP.23.

СТРУКТУРНЫЕ УСЛОВИЯ ЛОКАЛИЗАЦИИ ЗОЛОТОГО ОРУДЕНЕНИЯ В ПРЕДЕЛАХ ТУТХУНСКОГО РУДНОГО ПОЛЯ (ЦЕНТРАЛЬНАЯ ЧАСТЬ МАЛОГО КАВКАЗА)

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Резюме. Исследованы золотоносные участки рудного поля, сходства и различия структурных условий их образования, элементный и минеральный состав руд, различные метасоматиты-пропилиты, березиты и особенно вторичные кварциты. Определены основные закономерности размещения оруденения в плане, на флангах и на глубину.

Золоторудная минерализация может быть рассмотрена в плане некоторых региональных особенностей геологического развития Малого Кавказа, определивших благоприятное сочетание в этом районе геологических условий и тем самым намечающих естественные границы рудного поля, а также в плане частных элементов структуры, определяющих структурное положение и строение золоторудных образований. Интрузивные и субвулканические породы верхнеэоценового возраста представляют единый комплекс, формируют в районе Казыханлы-Заргулинский массив, приближающийся к субвулканической фации магматических образований. Поле развития золоторудных образований охватывает преимущественно выходы гранитоидных пород массива и его экзоконтактовые ореолы, куда проникают обильные дайки, наиболее поздние члены верхнеэоценового комплекса интрузивных образований. На этой площади золоторудная минерализация локализуется в узких и протяженных зонах сильно измененных пропилитизированных пород массива и его ближних ореолов. Распределение их в пределах рудного поля весьма неравномерное. Местами такие зоны образуют сближенные свиты, в большинстве случаев совпадающие с полями наиболее обильного развития дайковых пород.

Как видно, золотоносные зоны парагенетически связаны с дайками, завершающими развитие гранитоидных интрузивных комплексов. Те и другие, наиболее близкие по времени развития магматического и послемагматических процессов, используют в своем размещении единые структуры более раннего периода развития.

Ключевые слова: *центральная часть Малого Кавказа, месторождение, участок, структура, эпитермальное, золото, серебро, вторичные кварциты, генетические особенности, рудообразование, золото-кварцевые рудные зоны*

TUTQUN FİLİZ SAHƏSİ DAXİLİNDƏ QIZIL FİLİZLƏŞMƏSİ LOKALLAŞMASININ STRUKTUR ŞƏRAİTİ (KİÇİK QAFQAZIN MƏRKƏZİ HİSSƏSİ)

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Xülasə. Filiz sahəsinin qızıl daşıyan sahələrinin əmələgəlmələrinin oxşar və fərqli struktur şəraitləri, filizlərin element və mineral tərkibi, müxtəlif metasomatitlər-propillitlər berizitlər və xüsusən törəmə kvarsitlər tətqiq edilmişdir. Filizləşmənin planda, cinahlarda və dərinlikdə əsas yerləşmə qanunauyğunluğu müəyyən edilmişdir. Planda qızıl minerallaşmasına Kiçik Qafqazın geoloji inkişafının, o cümlədən rayonda əlverişli geoloji şəraitin birləşmələrini, filiz sahəsinin sərhədlərini, həmçinin planda qızıl filizi əmələgəlməsinin quruluşunu və struktur vəziyyətini müəyyən edən bir sıra regional xüsusiyyətləri kimi baxmaq olar. Gec eosen yaşlı intruziv və subvulkanik süxurları rayonda Qazıxanlı-Zərqulu massivi əmələ gətirərək vahid massivi əks etdirir. Qızıl filizi əmələgəlmələrinin inkişaf sahəsinin çıxışını və onun ekzotəmas oreolunu əhatə edir. Burada gec eosen intruziv kompleksinin daha gec üzvləri və daykalar təzahür edir.

Bu sahədə qızıl filizi minerallaşması massivin güclü dəyişilmiş propillitləşmiş süxurların ensiz və uzanmış zonalarında və onun yaxın oreollarında lokallaşırlar. Bəzi yerlərdə belə zonalar, əksər hallarda dayka süxurlarının daha geniş inkişaf tapdığı sahələrdə yaxınlaşmış yaruslar əmələ gətirir. Ən çox rast gəlinən sahə və yaxınlaşmış filiz zonası filiz sahəsi kimi ayrılır.

Göründüyü kimi, qızıl filizi daşıyan zonalar qranitoid intruziv kompleksinin yekun inkişafının daykaları ilə əlaqədardır. Zamanca inkişafı üzrə daha yaxın maqmatik və postmaqmatik proseslər onların yerləşməsində əvvəlki inkişaf dövrünün vahid strukturlarından istifadə edir. Bu zaman filiz damarları ilə tamamlanmış çat strukturlarının vəziyyəti tamamilə ətraf süxurların mexaniki xüsusiyyətlərini təyin edir.

Açar sözlər: *Kiçik Qafqazın mərkəzi hissəsi, yataq, sahə, struktur, epitermal, qızıl, gümüş, törəmə kvarsitlər, genetik xüsusiyyətlər, filiz əmələgəlmə, qızıl-kvarslı filiz zonaları*