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REGIONAL STRUCTURAL CONTROL ON ORE DEPOSITS LOCATION IN THE CENTRAL CAUCASUS SEGMENT OF AZERBAIJAN: AN INVESTIGATION OF THE ROLE OF TECTONIC DISLOCATIONS

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Summary. The most important distinctive feature of the central part of the Central Caucasus Segment of Azerbaijan (the Lesser Caucasus) is the connection of mineralisation with ore-concentrating dislocation systems. These systems are characterized by extensive northwestern trending fault zones. Major ore deposits (Zod, Tutkhun, etc.) are located at their intersections with meridional strike zones. An important part of the local structure is the Zod tectonic node, which has a significant influence on the localisation of gold mineralisation. One of the main factors determining the position of the area is its confinedness with the gabbroic massif occupying the tectonic centre, as well as the linearly extended contact strip of ultramafic igneous rocks and gabbro plates. Gold mineralisation in the Tutkhun area is localized in narrow and prolonged zones of intensely altered rocks of the granitoid complex and its exocontact halos. There are many dikes that are the most recent members of the intrusive formations. The distinct geological and structural characteristics of mineralisation identified at the Agduzdag deposit suggest a complex stockwork-style ore body, which integrates multiple structural elements. The Zod-Tutkhun-Agduzdag block represents a triune system of dislocations forming a geologically significant structural framework. The intersection of these dislocations has given rise to a complex tectonic center with a heterogeneous structural composition serving as the focal point for a multi-stage ore-forming process. These findings provide new insights into the potential for gold mineralisation within the Central Caucasus Segment of Azerbaijan and the southeastern part of the region, where similar geological conditions prevail.

Introduction

The authors' work has established that the occurrence of dissimilar gold-quartz-sulphide, gold-quartz and gold-quartz-tellurium mineralisations of the Central Caucasus Segment of Azerbaijan are different types of ore-magmatic systems with different types of sections.

Information on the geological settings of these fields and partially on the structural conditions of gold mineralisation localisation are given in the works by M.A.Kashkay, I.G.Magakyan, G.A.Tvalchrelidze, V.M.Babazadeh, V.I.Aliyev, T.N.Nasibov, Sh.D.Musayev, M.M.Konstantinov, E.S.Suleymanov, R.K.Hasanov, etc.

The most important peculiarity of the field under study is the connection of mineralisation with through ore-concentrating dislocations (Thomson, 1988; Favorskaya et al., 1974), which was first established by M.A.Kashkay (Kashkay, Tamrazyan, 1967). Later, V.M.Babazadeh (Babazadeh, 1975; Babazadeh et al., 2003) revealed that gold ore fields are located at the intersection of latitudinal and meridional faults representing a complex network of deep structures. Their certain independence and duration of development is emphasized by the presence of specific igneous and sedimentary formations. In this regard, the author developed a concept of them as zones of deep-laid permeability, repeated revival causing the basic divisibility of the lithosphere into systems of blocks of different dimensions. The deep penetration of ore-concentrating structures is also supported by such peculiarities as the extent, magma saturation, significant facies alterations of rocks, sharp gradients of sediment thickness, the presence of mineral formations of different ages, etc.

The triune complex system of faults developed within the Zod-Tutkhun-Agduzdag block is of great interest among the fractures (Babazadeh, 1975; Babazadeh et al., 2003; Konstantinov, 1984; Konstantinov, Bochek, 1984; Kostenko et al., 2001). The block turned out to be the most optimal for the localisation of mineralisation, where a complex tectonic centre of heterogeneous structure was formed leading to a multi-stage ore-forming process.

The system is characterized by straightness and subvertical position of fault planes; the orientation and density of dislocations in different parts are not the same. All other directions are suppressed by a system of sublatitudinal strikes in the central part of the block. It is quite possible that the existing network of differently oriented dislocations is a reflection of the primary heterogeneity of the Earth's crust. At the same time, having a deep nature, they do not penetrate to depths below the lithosphere judging by the granitoid composition of igneous melts.

Geodynamic settings and conditions of field formation

The history of the geodynamic development of the Caucasian folded mountain structure including the gold ore strip of the central part of the Lesser Caucasus was determined by the interaction of microcontinents – "fragments" of the Afro-Arabian and Eurasian lithospheric plates. According to reconstructions (Baba-zadeh et al.., 2020; Gugushvili, 2017), early pre-collisional heterogenization of the Earth's crust, which was provoked by the spreading of microplates occurred during the formation of the ocean floor (The Lesser Caucasus branch of the Neotethys) and rift depressions on the margins of microplates (Early Bajocian volcanics of the South Caucasus and subalkaline volcanites of the North Caucasus), and later heterogenization (subduction period – Late Bajocian-Early Cretaceous) in the formation of a volcanic island arc (Abdullayeva, 2018; Kostenko et al., 2001) on the southern margin of the South Caucasus microcontinent, and on the northern margin of the marked continent occurred in the formation of flysch troughs, rift structures (Late Jurassic Colchian alkaline basalts) with the simultaneous growth of neighbouring blocks.

Tectonic processing of previously formed geomorphostructures continued at the collision stage. This age boundary should be associated with collisional compression accompanied by a first-order dislocation, volcanic depressions became isolated along transverse structures, the process of rafted flyschoid sediments of marginal marine origin began, as well as the obduction of oceanic sediments onto the margins of contacting microplates, which later led to the formation of collisional structures of suture zones (Baba-zadeh et al., 2020; Gordienko et al., 2019). One of them is the Goycha-Hakari zone (it is called a trace of the closed Lesser Caucasus branch of the Neotethys) – composed of the early and late Cretaceous deformed volcanogenic-sedimentary deposits consisting of siliceous shales, sodium basalts with tectonic ultrabasic melange. Glaucophane schists are found in the western part of the latter development.

Intensive convergence of microplates predetermined the modern appearance of the folded mountain structure, which is perceived as a pile of heterogeneous blocks in allochthonous relationships (Babazadeh et al., 2020). Fields occupy clear spatial and temporal positions in the folded mountain structure. For example, sulphide-rich hydrothermal-sedimentary deposits of the Eastern Caucasus (Filizchay, etc.) are associated with complexes of the basins of the paleomarginal sea. The time of their ore genesis is limited by the Early Jurassic – Early Middle Jurassic, and the space – by local depressions of the paleo-marginal sea. Significant accumulations of volcanogenic epigenetic ores of precious and non-ferrous metals are associated with complexes that mark a fundamental restructuring of tectonic regimes (the beginning of subduction and collisional stage) (Abdullayeva, 2018). Research conducted in recent years in the central part of the Lesser Caucasus showed that lithogeodynamic complexes are specialized in magmatic chromite (Heydar, etc.), plutonogenic and volcanogenic gold ore (Tutkhun, Zod, Soyudlu, Agduzdag, etc.) and amagmatic mercury, mercury-antimony-arsenic (Shorbulag, Agyatag, Lev) fields.

Peculiarities of the geological framework and genetic types of gold ore fields

The Tutkhun ore field covers the upper reaches of the river of the same name, a large right inflow of the Terter River (Abdullayeva, Novruzova, 2023; Babazadeh и др., 2024; Suleimanov, 1982). The ore field within the area under consideration occupies a central place with an area of about 20 km^2. The geological settings of the ore field include mainly post-Upper Eocene subvolcanic and hypabyssal granitoid bodies of the Gazikhanli-Zergulu (Gazikhanli-Zergulu) intrusive complex (absolute age is 43-44 million years – middle Eocene) and comagmatic volcanites (Eocene andesites and their tuffs) developed within adjacent synclinal structures. Apparently (Baba-zadeh, 1975; Baba-zadeh и др., 2024; Svirko, 1973), they represent a single volcano-plutonic association. The intrusion is mapped from the surface as a large fractured pluton elongated in the northwest direction (300-310º) along the Tutkhun River valley, with a strike length of more than 10 km, a dip of at least 300 m, and a thickness of 0.2-2 km.

Probably, the massif fixes one of the Early Paleogene faults accompanied by regional structures of the region, in particular, with the axis of the Gazıkhanli anticlinal fold stretching more than 20 km in the north-west direction across the entire area of the ore field (Fig. 1). The wingspan of the fold reaches 4 km.

The bodies are stock-shaped up to 3 km^2 in size and up to 1 km in diameter. Contacts with host rocks are sharp, cross-cutting, sometimes subconformable and tectonic in places. Contact alterations are expressed in hornfels formation, scarn mineralisation, epidositisation. The massifs are characterized by banding and the occurrence of xenoliths of host rocks. The width of the band of altered rocks is 250-300 m. Low-temperature alterations are represented by silicification, sericitisation and carbonatisation.

This is followed by the formation of vein facies of rocks, as well as subvolcanic rocks of the same complex, at the final stage of which occurrences of gold, silver, molybdenum are localized including the Tutkhun ore field. The dykes are predominantly pre-ore concentrated in the apical and marginal parts of the intrusive massifs, usually in the host rocks.

The largest fractured structure within the ore field is the Zod-Tutkhun fault (or a series of subparallel upthrusts, upthrust-shifts) of north-west strike, which coincides with the general orientation of the folded structures and can be observed for tens of kilometres (Baba-zadeh, 1975; Konstantinov et al., 1984). The dislocation was activated in Eocene to Pliocene, which led to the intrusion of intrusive masses of the Gazikhanli-Zergulu complex. The fault is accompanied by intersecting ore-bearing fractures bearing traces of active hydrothermal alterations, which are reminiscent of listvenites (zones closest to the fracture cavity) in the body of the intrusion and in the host volcanogenic-sedimentary rocks. They usually contain ore bodies.

Large dislocations, folded forms and smaller fracturing, which are observed in the ore field are characterized by a close relationship causing a wide occurrence of general fracturing.

The industrial ore bodies of the field are represented mainly by hydrothermally altered gold-bearing zones demonstrating many variations depending on the types of host rocks, the composition of ore fluids, spatial position, fluid/rock ratio, etc. (Li et al., 2022). Active deformation and high fluid pressure promote interaction of the fluid with the rock and formation of quartz veins (Phillips, 2022). The main part of the metal is contained in quartz veins in the contours of ore zones. According to the author, gold is deposited mainly by reduction and sulfidation of the host rocks. Most often, these veins are confined to shear cracks in the bodies of granitoid massifs. Their length is 100-200 m, rarely up to 400-500 m, thickness 15-20 cm and more. Rich accumulations of pyrite, molybdenite, fahlore, etc. have been observed in separate quartz veins. The occurrence (Gizilitan) is also associated with a volcanic pipe (Babazadeh et al., 2003), gold-bearing throughout the entire cross-section, containing Ag, Mo, Cu, Pb and Zn. The pipe was observed to a depth of 340 m.

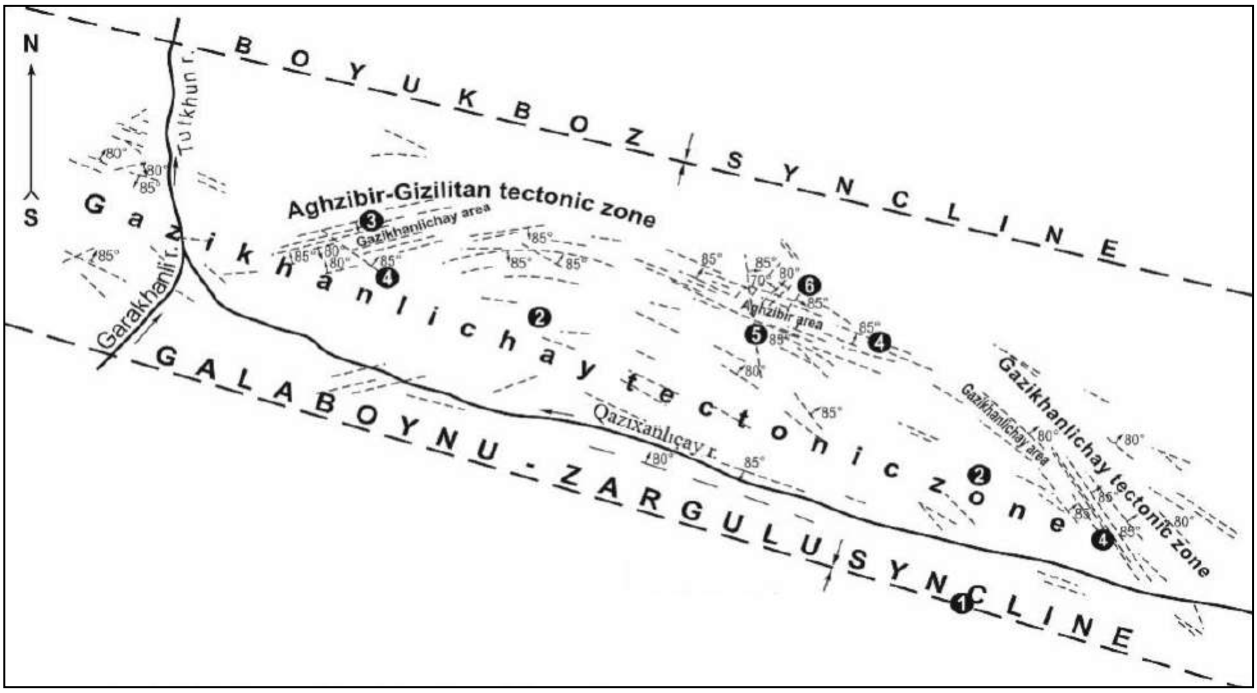

Fig. 1. 1 – Syncline axes; 2 – Gazikhanlichay tectonic zone; 3 – gold-bearing zones of north-eastern strike; 4 – gold-bearing zones of north-eastern strike (near latitude); 5 – gold-bearing zones of north-eastern strike (near meridional); post-mineral fault planes of northeast strike

There are about 10 gold-bearing areas (Gazikhanli, Aghzibir, etc.) from east to west differing in the nature of mineralisation and localized in rocks of different stratigraphic levels. Gold occurs in 3 forms: native, finely dispersed in quartz and isomorphic impurity in sulphides and sulfosalts. The largest amount of gold is finely dispersed in quartz, as well as isomorphic impurity in sulphides (Babazadeh, 1975; Babazadeh et al., 2003; Volkov et al., 2011; Volkov et al., 2018).

The field belongs to the class of sulphidic epithermal gold ore quartz-gold-sulphide formation. The span of mineralisation is approximately 300-400 m to 500 m from the daylight surface at a depth.

The Tutkhun field like the Zod has a similar tectonic setting and geological characteristics with typical orogenic gold fields of the North-East of Russia (Shkolnoye), Eastern Transbaykal (Talatuy), Eastern Kunlun (China), Mergui (Myanmar), Canadian Appalachians of the Baie Verte Peninsula (Canada), etc. (Volkov et al., 2011; Piercey et al., 2021; Gong et al., 2023; Hlaing et al., 2021).

The Zod ore field is located on the watershed of the Zangezur Range along the border of Armenia and the Kalbajar region of Azerbaijan covering the spurs and summit of Mount Misgainakh. The total area occupied by the ore field is 30-35 km^2. In accordance with the boundary line, a major part of the field (about 73%) is located in the territory of Azerbaijan. The ore field is located in the obducted basite-ultramafic complex of the Lesser Caucasus suture zone activated in the Neogene. As a result, crystalline schists of the Precambrian basement and rhythmically early Senonian layered volcanogenic-sedimentary deposits are raised to the surface (Fig. 2). The allochthonous block composed of serpentinised ultrabasic rocks and gabbroids is intensively fragmented and complicated by granodiorite porphyry dykes intruding into it (Baba-zadeh et al., 2020).

The field is also located in a distinctive block limited on all sides by faults and, in turn, dissected into a number of tectonic blocks – sections limited by faults (Amiryan, 1984; Babazadeh, 1975; Babazadeh et al., 2003; Baba-zadeh et al., 2020; Konstantinov et al., 1984; Melikyan, 1977).

The most significant is the raised Central block. This area is almost entirely located on the territory of Azerbaijan.

The main ore-concentrating structure is the Zod sublatitudinal fault along which tectonic displacements occurred repeatedly. The latter led to strong processing of ultrabasic rocks, gabbroids and other rocks, which indicates that this structure is continuous.

The Ketidag and Zod-Tutkhun tectonic sutures are associated with the Zod fault accompanied by crushing zones and metasomatic new formations with gold ore mineralisation.

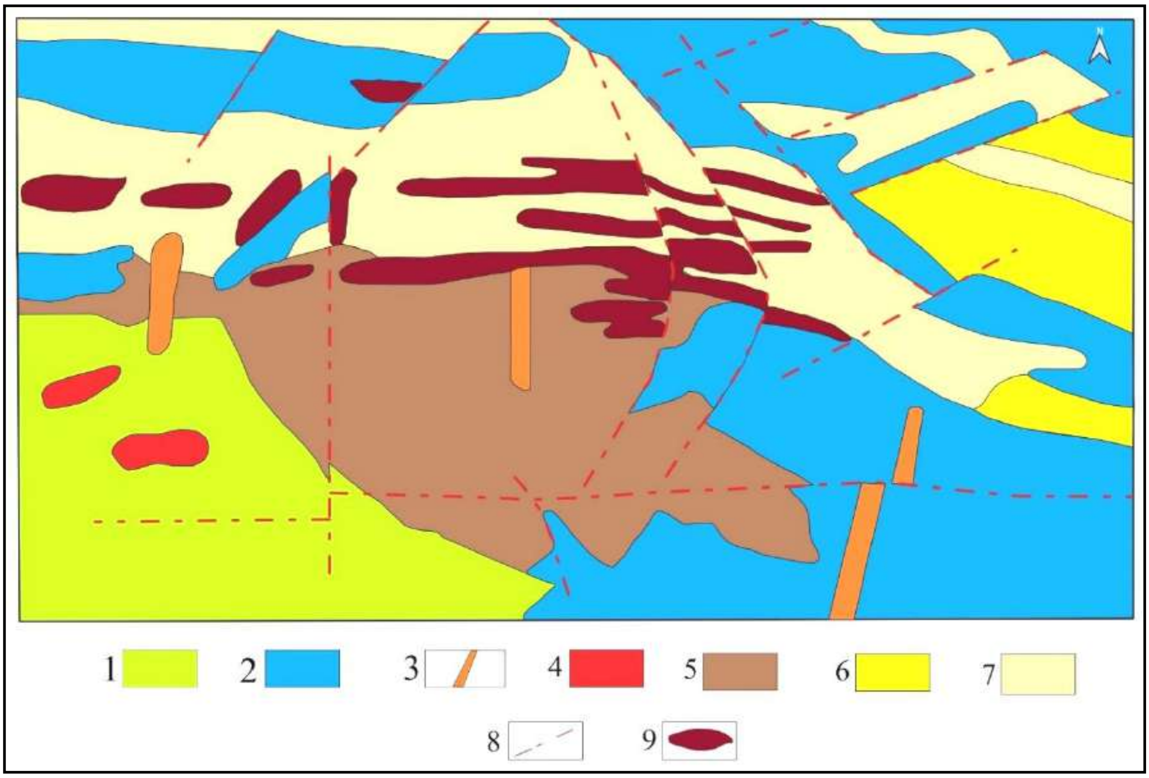

Fig. 2. Geological map (in part schematic) of the Zod ore field (according to data of the Zod geological party). 1 – Coniacian-Maastrichtian limestones and marls; 2 – basalts, their lava breccias and tuffite; 3 – dykes of granodiorite porphyry; 4 – quartz diorite; 5 – gabbro; 6 – amphibolite; 7 – serpentinized peridotite; 8 – fractures; 9 – ore-bearing zones

The Zod gabbroic massif (Martirosyan, 1990), which occupies the central axial position in the tectonic wedge and occupies more than 50% of its total area also plays a significant role in ore formation. The confinement of industrial mineralisation (Melikyan, 1977; Baba-zadeh и др., 2024) to linearly elongated plates of ultrabasic rocks enclosed between contacts of gabbroids is quite characteristic here. The persistent contact band is represented by sublatitudinal extended zone of pre-ore quartz-carbonate metasomatites-listvenites and listvenite-like rocks with gold ore mineralisation marking the Zod fault. It is associated with the veinlet-impregnated type of mineralisation (mineralised gabbro).

Gold mineralisation ore bodies are consistent along the strike and dip and are represented by vein zones, lens veins and veins of quartz with sulphide mineralisation. Stockwork bodies of impregnated and veinlet ores in metasomatite, sometimes beyond them are no less important. The gold content in them is high – from 1.5-2 to 4-5 g/t and more. The development of ore column is typical in the most intensively tectonically processed areas characterised by the greatest thickness of ore bodies and high metal content in them (bonanzas).

Ores are characterised by a complex, multicomponent composition (Amiryan, 1984). Useful components of ores are gold, silver, tellurium, bismuth, copper and zinc; harmful impurities are arsenic. Gold and silver are of industrial importance. The overwhelming amount of gold (95.98%) occurs in free form, in intergrowths and compounds with tellurium. Dispersed gold is concentrated in pyrite, and large native gold is associated with sulphides, tellurides and vein minerals.

The deposit contains zones of exceptionally high-grade gold mineralisation (ranging from 840 to 953 g/t), with an average gold content of 9.24 g/t, silver at 15.67 g/t, and tellurium at 30.9 g/t. The Au\Ag ratio is approximately 1:7. Tellurium represents a significant accessory element within the ore, occurring predominantly as discrete telluride minerals, which suggests a notable geochemical enrichment and potential genetic linkage to a telluride-bearing epithermal system. The ores belong to the gold-quartz-tellurium formation type (Amiryan, 1984). Post-Lower Oligocene-Lower Miocene age of mineralisation is allowed (Baba-zadeh et al., 2020).

The vertical extent of mineralisation is determined at 500 m from the daylight surface taking into account the values of ore-bearing intensity by the hanging wall and footwall of ore bodies. The basic-ultrabasic complex has undergone irregular greenstone alteration (amphibole-quartz-albite-epidote association). The Zod shows some similarities to ancient fields in greenstone belts, such as Kirkland Lake and Hollinger in Canada or Nosquil in California (Nekrasov, 1988).

The Soyudlu ore field lies to the east and southeast of the Zod field covering the basin of the river of the same name in the upper reaches of the Levchay River (left tributary of the Terter River) and the Sarıyal-Heydari watershed between that river and the Terter River.

More than 20 gold-bearing zones of hydrothermally altered rocks have been observed here representing a set of lenses and lens-veins of listvenites and controlling by northwestern-oriented dislocations. Their sizes fluctuate from the first hundred meters to several kilometres reaching 5-6 km and more with thickness from 2-15 to 40-50 m.

Unlike the Zod ore field, the development intensity of ore-concentrating faults of submeridional strike decreases within the Soyudluchay area and a system of echeloned low-amplitude fractures (Eastern-Poludlu, Gunashli, etc.) of north-eastern direction occurs. According to geological explorations, the Zod gold-localizing structure passes to the left slope of the Soyudluchay River and can be observed with representative parameters of gold mineralisation at a distance of more than 1 km.

The data, mainly geological and structural, as well as distinctive linear geophysical anomalies in combination with points of primary gold content and placer signs of gold suggest that the gold-concentrating zone, which is not quite clearly expressed on the surface can be observed at least 2 km to the west.

This is confirmed by the intersection of gold-bearing intervals that exposed ore zones (Au – 2.5-11.0 g/t). Further, this zone called Zod-Soyudlu (Baba-zadeh et al., 2003) is intersected by borehole No. 14 with a shaft length of 12.3 m (in the interval of 129-141.3 m) and an average gold content of 3.2 g/t in the eastern direction. A straight shaft of a driven adit at a depth of 558.0-585.8 m intersected a gold-bearing interval with a thickness of 27.8 m and a gold content of 10-42 g/t in the same area.

According to the set of facts, mainly geological and structural, the possible eastern continuation of the Zod gold-bearing zones passes along the left slope of the Soyudluchay River (Baba-zadeh, 1975; Baba-zadeh et al., 2003).

A somewhat hidden connection (through quartz-sulphides of the vein-veinlet zone in siliceous shale rocks and serpentine schists) between the Damirchidam gold-bearing zone and the Gonur zone is also suggested. This means that against the background of the general dispersion of gold with the formation of local concentrations in gold occurrences, it is very likely that we are dealing with a large Zod-Damirchidam gold-concentrating structure characterised by almost ubiquitous gold mineralisation with localisation of significant concentrations in separate areas.

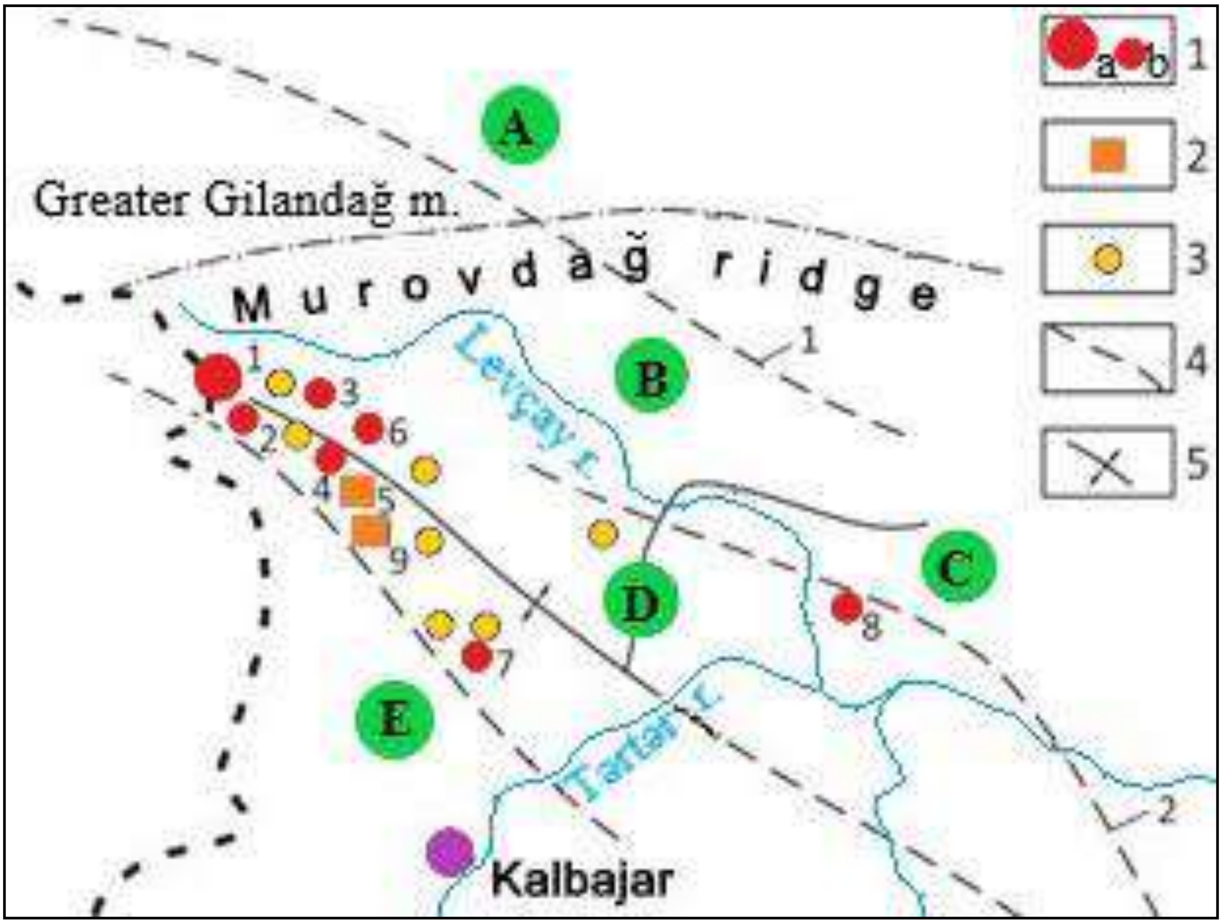

Fig. 3. The arrangement of the Soyudluchay group of gold ore objects. 1 – gold ore fields (a), occurrences (b) (red dots): 1 – Zod (field), 2 – Zod (occurrence), 3 – Gonur, 4 – Soyudluchay; 5 – Heydari, 6 – Damirchidam, 7 – Istibulag, 8 – Gamishli; 2 – chromite field (Heydari) (rectangle dots); 3 – placer gold aureoles; 4 – tectonic faults (the main ones: 1 – Murovdagh and 2 – Karabakh); 5 – axis line of the Almalı-Heydari anticlinal fold. A – Murovdagh uplift; B – Toraghachay trough; C –Karabakh uplift; D – Sarıbaba trough; E – Kalbajar superimposed trough

The Agduzdag field of gold-quartz formation was formed in a different geodynamic regime. It is located in the middle and upper reaches of the Zerchay and Zaylikchay rivers (left tributaries of the Terter River) on the border of Azerbaijan and Armenia (Fig. 3). The geological and tectonic position of the ore field determined its block structure (Babazadeh, 1975; Baba-zadeh et al., 2003; Ali-zadeh, 2003; Kostenko et al., 2001, Prokofiev et al., 2007), which are enclosed between the deep Lachın-Bashlıbel fault of the northwestern direction and its southern branch – the Delidag fault of the same strike. The block is bounded by the Terter submeridional fault from the east, which is a system of extension fracture-rupture. Stretching along the valley of the Terter River, the fault zone covers a strip about 2.0-2.5 km wide and is represented by multiple mineralised vein formations, densely intersecting the Middle Eocene volcanogenes along the southern border of the Agduzdag ore field. These rocks are dislocated in a series of crushed folds, complicated along the limbs and in the axial parts by reverse dislocations extending in a near-meridional direction (Fig. 4).

The structural bar of the ore field is the Ketidag and Shirvan deep faults of meridional direction with steep dip angles (70-85°), which are slightly inferior in prevalence to the zones of latitudinal and diagonal (mainly northwestern) strikes. There is a complex junction of the Shirvan, Ketidag and Agduzdag tectonic sutures to the east of the Terter orocline.

The zones of the mentioned faults are obviously observed in geophysical fields. The results of geophysical data suggest that the system of meridional dislocations exposing the ore-concentrating structure affects subcrustal depths. Meridional dislocations are partially deciphered in space images.

Another, no less significant Ketidag fault stretches along the Zangezur ridge starting from the Agduzdag field in the south to the Zod field in the north. The surface of its fault dips either to the southeast or to the northwest at steep angles of 60-80°. The dislocation forms three smooth foldings on the surface from which a number of small feathering fractures of south-eastern strike extend (Fig. 4).

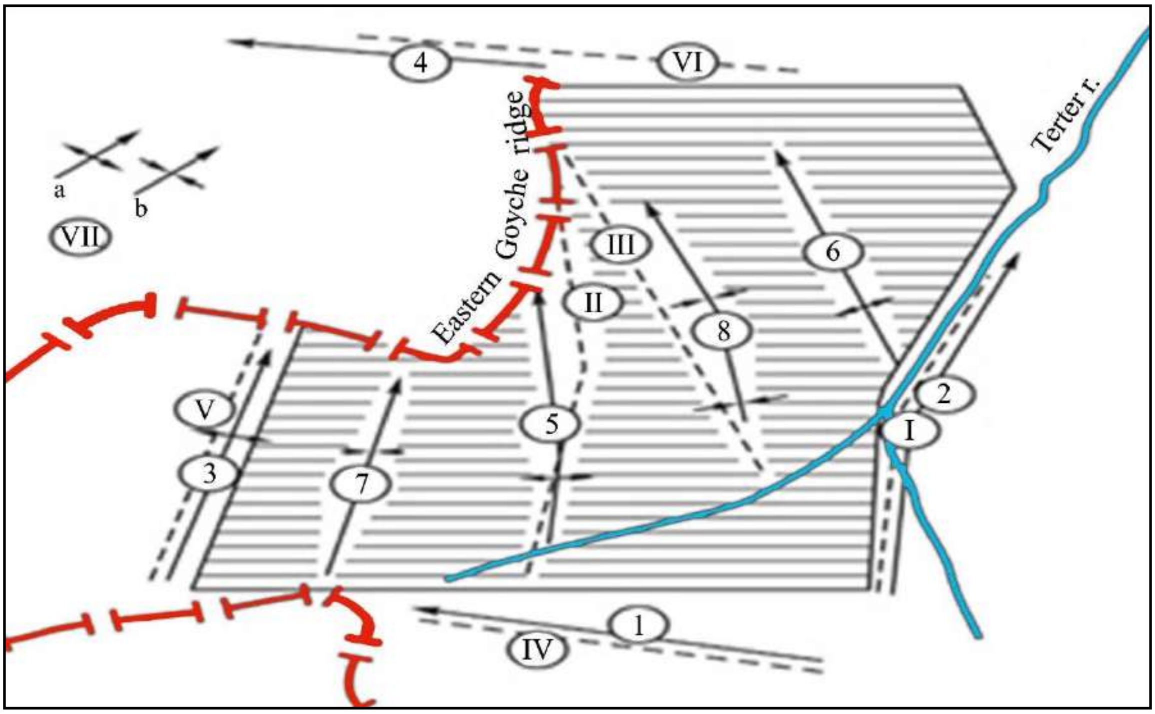

Fig. 4. Scheme of the tectonic structure of the Agduzdag ore field. The ore field is hatched. 1 – Garanlyg-Baghirsag - Garaaghaj anticline; 2 – Terter transverse anticline; 3 – Gurbaghalichay anticline; 4 – Goshabulag anticline; 5 – Zeylik anticline; 6 – Khanurli anticline; 7 – Ketidag syncline; 8 – Komurdag syncline; I – Terter fault; II – Shirvan reverse fault; III – Zeylik reverse fault; IV – Garaaghaj fracture; V – Gurbaghalichay fracture; VI – Goshabulag fracture; VII – axis and direction of plunge of anticlinal (a) and syncline (b)

The Agduzdag fracture (zone No. 3) is located 250-300 m west of the elevation point of 3335.6 m and can be observed at a distance of 1.3 km almost along the watershed ridge. The fracture is confined to a gold-bearing quartz vein accompanied by later quartz and quartz-carbonate veinlets (Fig. 5).

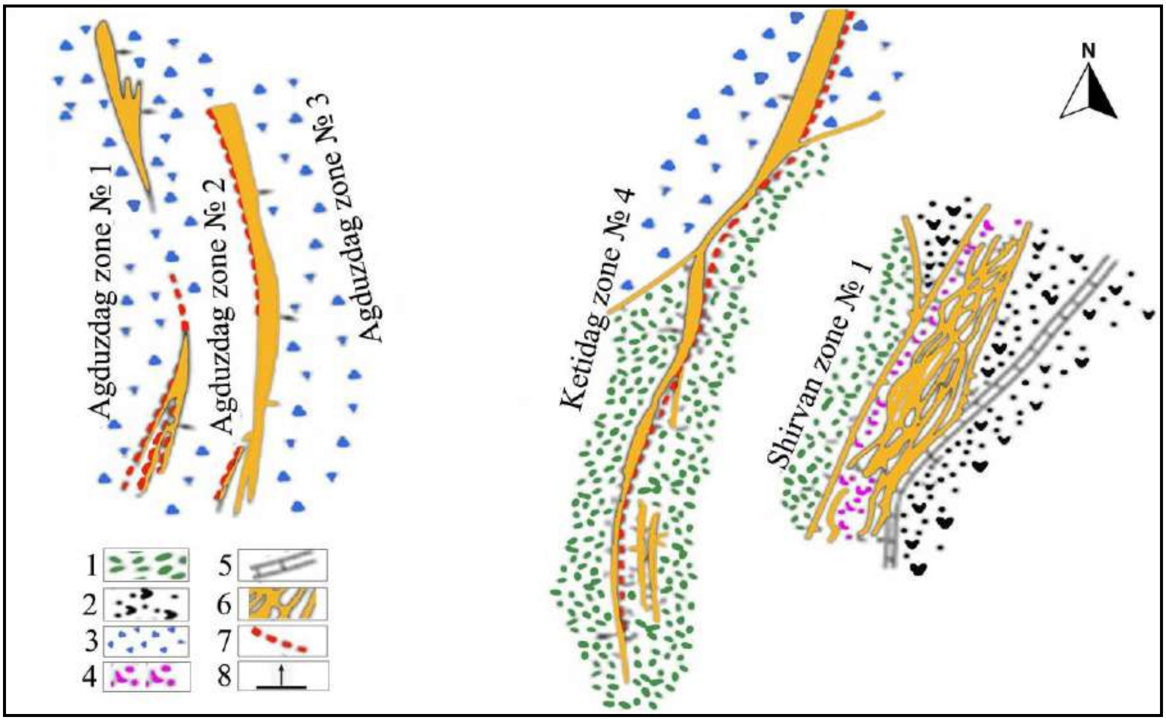

Fig. 5. Morphology of quartz-ore bodies of the Aghduzdagh gold ore field
1 – rhyolites and rhyolite-dacites (Mio-Pliocene); 2 – kaolinized and silicified andesite (Middle Eocene); 3 – andesite and andesite-dacite tuff-breccias, 4 – rhyolite dyke; 5 – syenite-porphyry dyke; 6 – ore bodies; 7 – fault-type tectonic fractures; 8 – dip angle

Exploration and prospecting works have identified more than one hundred silicified, kaolinized, and sometimes ferruginous-sulphide zones, usually healed by subvolcanic bodies (rhyolite dikes and lenses). The degree of hydrothermal alteration and gold ore mineralisation decreases gradually with distance from the selvedge part of the dykes.

Gold is not observed macroscopically, gold particles of 0.1-0.3 mm in size and light yellow in colour are rarely observed (Babazadeh et al., 2003; Volkov et al., 2018; Alizadeh, 2003).

The main mineral of the veins is inequigranular, predominantly fine-grained quartz up to chalcedony (95-98%) saturated with fluid inclusions. The share of ore minerals represented by pyrite, chalcopyrite, sphalerite, galena, magnetite, native gold, altaite, actinolite, rutile, etc. accounts for 2-3% of the total mass of ore.

Ore mineralisation is often confined to areas of quartz saturated with fluid inclusions. Inclusions, which are trapped in minerals, are classified as primary, primary-secondary and secondary. Microinclusions from minerals are represented by essentially liquid phase with an insignificant content of gas. Homogenization of these inclusions occurred in the liquid phase, which shows the hydrothermal nature of ore formation. The abundance of gas-liquid inclusions in minerals characterised by insignificant sizes provide to some extent additional data on the near-surface conditions of their formation at low and medium temperatures (340-180°C) with insignificant lithostatic pressure up to 200 atm.

The study provides insights into the genesis of orogenic gold ore fields in the Lesser Caucasus, with a particular focus on the Tutkhun ore field, emphasizing its structural controls, metallogenic evolution, and tectono-magmatic setting within the broader regional geodynamic context. Most researchers point to a close connection between gold ore mineralisation and the complex of volcanic-plutonic rocks of the Gazikhanli-Zergulu massif. First of all, such a connection is evidenced by the analysis of the distribution of impurity elements in the composition of rocks at all stages of massif formation in different facies of altered rocks and within the zones of gold ore mineralisation. All the above-mentioned rocks are characterized by a certain complex of through impurity elements among which Be, Se, Mo, Cu, Ag, Co, Au, Te and others occur constantly in above Clarke contents from 2 to 5-10 times. Moreover, each of the above-mentioned elements experiences a certain tendency in concentration or dispersion during the process of evolution of the massif rocks, their post-magmatic alterations and during the formation of mineralised zones. Comparative data on the content of the dispersed gold in rocks of the Gazikhanli-Zergulu massif of different formation times show that it accumulates gradually in rocks of later intrusive phases along with an increase in the content of volatile compounds in the same rocks. A close temporal connection between the dykes and ore zones formed under the preserved deformation plan is also observed. The close connection between them is also indicated by the similar complex of superimposed minerals in the composition of the dykes and the hydrothermal-metasomatic complex of minerals in the composition of the ore zones excluding the late complex of sulphides of the ore stage and the gold mineralisation.

A similar tectonic setting is also observed in the Zod and Soyudlu gold ore fields located 50-60 km to the north in the same tectonic zone of the Sarıbaba trough.

Besides the above, it should be stated that most genetic on orogenic gold fields that are associated with near-surface or magmatic-hydrothermal fluids are currently refuted from the point of view of the global mineral system model (Groves et al., 2020). The model of orogenic gold system supports a source of metal and fluid in the geological conditions in which mineralisation occurred and is applicable only to three of the twelve fields studied (Meyer, 2023). All other fields were formed most likely from a crustal source, which supports the crustal metamorphic model (Meyer, 2023).

Conclusion

The fault network of the region exhibits a well-organized structural framework characterised by distinct sublatitudinal, northwestern, and submeridional dislocation systems. The primary ore-controlling structures include the Agduzdag-Zod, Zod-Tutkhun, and Ketidag systems, each displaying key diagnostic features typical of this class of structures:

a) Association with long-lived linear fault systems, which have undergone multiple episodes of tectono-magmatic reactivation;

b) Anomalous landscape and structural-material heterogeneity resulting from intensive block fracturing, high-strain fault tectonics, the accumulation of nodes of long-term endogenous activity, and an increased concentration of igneous complexes of varying ages;

c) A diverse range of lithological formations and a broad temporal spectrum of mineralisation marking the most structurally stressed zones within ore-bearing fault systems.

Several key characteristics define the gold ore fields in the region:

1. Hypogene gold mineralisation is spatially controlled occurring in specific structural settings either in dome-shaped exposures or, conversely, in depressions within subvolcanic and hypabyssal granitoid bodies of the Late-Middle Eocene intrusive complex.

2. Significant occurrences of both ore and nonmetallic mineralisation are localized within the exocontact and endocontact zones of intrusive bodies. Due to the highly developed fractured nature of the host rocks, mineralisation is preferentially concentrated within spatially persistent northeast-trending fractures.

3. The ores are compositionally complex and exhibit a multi-stage formation history.

4. Ore bodies are classified into distinct structural types:

a) Those developed along steeply dipping thrust-shift faults and low-amplitude strike-slip faults oriented parallel to the axial plane of a major anticline and the longitudinal weld of a deep-seated fault (Zod, Soyudlu type);

b) Those controlled by steeply dipping intersecting fractures within host rocksoccurring primarily along fractures without significant displacement (Tutkhun type);

c) Those forming as an interconnected network of veins and veinlets developed along echeloned minor fractures with diagonal, longitudinal, and transverse orientations (Agduzdag type).

A key exploration criterion of gold mineralisation in adjacent areas of the Central Caucasus Segment of Azerbaijan is the close structural relationship between gold-bearing veins and dyke intrusions associated with granitoid intrusive complexes. These magmatic and post-magmatic features, which are formed within similar temporal and structural frameworks, tend to utilize the same ore-controlling fault systems.

The most promising areas of gold mineralisation are those hosting Paleogene-Neogene intrusive formations petrochemically related to the gabbro-monzonite-granodiorite series. These favorable zones are typically located at the margins of intrusive rock outcrops, where they dip beneath porphyritic volcanic rocks, argillites, and limestones of the Upper Cretaceous stratigraphic sequence. In most cases, these prospective areas are closely associated with subvolcanic facies rocks (monzonite-porphyrites) suggesting a strong spatial control of ore-bearing zones by the highest (near-surface) levels of intrusive massifs.

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РЕГИОНАЛЬНЫЙ СТРУКТУРНЫЙ КОНТРОЛЬ РАЗМЕЩЕНИЯ РУДНЫХ МЕСТОРОЖДЕНИЙ В АЗЕРБАЙДЖАНСКОМ СЕГМЕНТЕ ЦЕНТРАЛЬНОГО КАВКАЗА: ИССЛЕДОВАНИЕ РОЛИ ДЛИТЕЛЬНО РАЗВИВАЮЩИХСЯ ТЕКТОНИЧЕСКИХ ДИСЛОКАЦИЙ

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Резюме. Важнейшей особенностью центральной части Малого Кавказа является связь оруденения с рудоконцентрирующими системами нарушений. Они представлены широкими северо-западного простирания зонами разломов. В их пересечении с зонами меридионального простирания локализуются крупные рудные поля (Зодское, Тутхунское и др.). Выделяются также широтные и северо-восточные зоны региональной трещиноватости, которые оказывают влияние на позицию рудных полей. В строении последних важная роль принадлежит локальным концетрическим структурам Зодского рудного поля, сыгравшим важную роль в локализации золотого оруденения. Среди главных факторов, определяющих позицию месторождения – приуроченность его к габбровому массиву, занимающему центральную позицию в тектоническом узле, а также к линейно вытянутой контактовой полосе пластин гипербазитов и габброидов. В Соютлинском рудном поле интенсивность развития рудоконцентрирующих разломов близмеридионального простирания обусловлена системой эшелонированных малоамплитудных разрывов с резко обогащенными участками оруденения с наибольшими мощностями рудных тел и высокими содержаниями в них металла, образующих бонанцы. В Тутхунском рудном поле золотая минерализация локализуется в узких и протяженных зонах интенсивно измененных пород гранитоидного комплекса и его экзоконтактовых ореолов, куда проникают обильные дайки, наиболее поздние члены интрузивных образований. Своеобразие выявленных геолого-структурных особенностей оруденения на Агдуздагском месторождении, четкое и характерное их проявление позволили выделить сложную штокверковую форму рудного тела, комбинированную и сочетающую в себе отдельные структурные элементы. Весьма интересной структурой представляется триединая сложная система нарушений, слагающая Зод-Тутхун-Агдуздагский блок, в результате сочленения которых образовался сложный тектонический узел гетерогенного строения, оказавшийся ареной развития полиэтапного рудообразующего процесса. Выдвинутые положения открывают новые возможности для прогноза золотого оруденения как в пределах центральной части Малого Кавказа, так и в юго-восточной части региона, отличающихся сходным геологическим строением.

Ключевые слова: *Малый Кавказ, рудоконцентрирующие структуры, рудное поле, глубинный разлом, золото, дайка, гидротермальное изменение*

MƏRKƏZİ QAFQAZIN AZƏRBAYCAN SEQMENTİNDƏ FİLİZ YATAQLARININ YERLƏŞMƏSİNDƏKİ REGİONAL STRUKTUR NƏZARƏT: UZUN MÜDDƏT İNKİŞAF EDƏN DİSLOKASİYALARIN TƏDQİQİ ROLU

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Xülasə. Kiçik Qafqazın mərkəzi hissəsinin mühüm xüsusiyyəti filizləşmənin filizi konsentrasiya edən pozulma sistemləri ilə bağlılığıdır. Onlar şimali-qərb istiqamətli qırılma zonaları ilə təmsil olunmuşlar. Bu sistemlərin meridional istiqamətli zonalarla kəsişməsi iri filiz sahələrinin (Zod, Tutxun və s.) lokallaşmasına səbəb olmuşdur. Enlik və şimali-şərq istiqamətli regional çat zonaları da ayrılır. Qızıl filizləşməsinin lokallaşmasında Zod tektonik qovşağı mühüm rol oynayır. Yatağın mövqeyini təyin edən əsas faktorlar: filiz qovşağında başlıca yer tutan qabbro massivi, habelə kontakt zolaqda hiperbazitlərlə qabbroidlərin xətti uzanmış plastinləridir. Söyüdlü filiz sahəsində konsentrasiya edən parçalanmaların inkişafının intensivliyi şimali-şərq istiqamətli kiçik amplitudalı eşolonlaşmış pozulma sistemlərilə təyin edilir; pozulmaların filizləşmə ilə zənginləşmiş məntəqələrində böyük qalınlıqlı filiz kütləri əmələ gəlmişdir; onlarda metalın miqdarı yüksəkdir, bir sıra hallarda bonantslar yaranmışdır. Tutxun filiz sahəsində diqqəti cəlb edən xüsusiyyət qranitoid kompleksinin və onun ekzokontakt oreolunda hidrotermal dəyişmiş süxurlarda ensiz və böyük məsafəyə uzanan qızıldaşıyan minerallaşma zonalarının aşkar edilməsidir. İntruziv əmələgəlmələrin ən gec üzvü olan daykalar bu zonalara nüfuz etmişdir. Ağduzdaq yatağının da özünəməxsus geoloji-struktur xüsusiyyəti vardır; mürəkkəb, bir növ ayrı-ayrı struktur elementlərin vəhdəti, ştokverk formalı filiz kütləsinin əmələ gəlməsinə də imkan yaratmışdır. Zod-Tutxun-Ağduzdaq blokunun əmələ gətirdiyi mürəkkəb pozulma sistemləri və onların üzvləşməsi nəticəsində heterogen mənşəli tektonik qovşaq yaranmışdır; o, cox mərhələli filiz əmələgəlmə prosesinin inkişaf arenası olmuşdur. İrəli sürülən iddialar istər Kiçik Qafqazın mərkəzi hissəsində, istərsə də bu ərazinin geoloji quruluşu ilə fərqlənən cənubi-şərqində, qızıl filizləşməsinin proqnozlaşdırmasına geniş imkanlar yaradır.

Açar sözlər: *Kiçik Qafqaz, filizə nəzarət edən strukturlar, filiz sahəsi, dərinlik qırılması, qızıl, dayka, hidrotermal dəyişmə*