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PREDICTIVE SEARCH MODEL OF GOLD MINER IN THE KULDZHUKTAU MOUNTAINS SOUTH-WEST-TYAN-SHAN

Odil Takhirdjanovich Razikov
Chief Researchers, State Enterprise "IMR", State Committee For Geology Of The Republic Of Uzbekistan. Tashkent City, T. Shevchenko Street, 11a, Uzbekistan, odil.razikov@mail.ru.
Saodat Torexanovna Maripova
Chief Researchers, State Enterprise "IMR", State Committee For Geology Of The Republic Of Uzbekistan. Tashkent City, T. Shevchenko Street, 11a, Uzbekistan, maripova.s@inbox.ru.

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Abstract:
This article presents the main geological (lithological, structural, magmatic, metasomatic, mineological-geochemical, etc.) factors of the location of mineralization in the Kuldzhuktau mountains. The paper notes the theory of the metamorphogenic-sedimentary genesis of gold ore mineralization, according to which, in the process of metamorphism, gold from the rocks of the amphibolite facies is carried out by fluids along tectonic shear zones and is deposited among the overlying rocks of the greenschist facies.
The results of the study of thematic parameters of the relationship of gold mineralization with the structural elements of the region are described in more detail; they show that, among the variety of ore-controlling structural factors, meridional - transverse faults are of great information value. According to our field observations, it was established that the Taushan ore field includes a series of NNE and NE quartz veins.

Keywords: Lamprophic dikes, compression deformation, fault-strike-slip, gold-quartz, Taskazgan, Taushan-Adylsay-Yangikazgan trend, beresitization, antimony and mercury, basaltoid, vein and vein-vein morphology, geochemical, metasomatic.

In the southeast of the Central Kyzyl Kum desert, which is a world famous gold and uranium province, there is a relatively poorly studied alpine uplift - the Kuldzhuktau mountains.

The mountains are composed in the core by rocks of the pre-Mesozoic folded basement, along the periphery - by deposits of the Meso-Cenozoic sedimentary cover and elongated in a sublatitudinal direction from northwest to southeast.

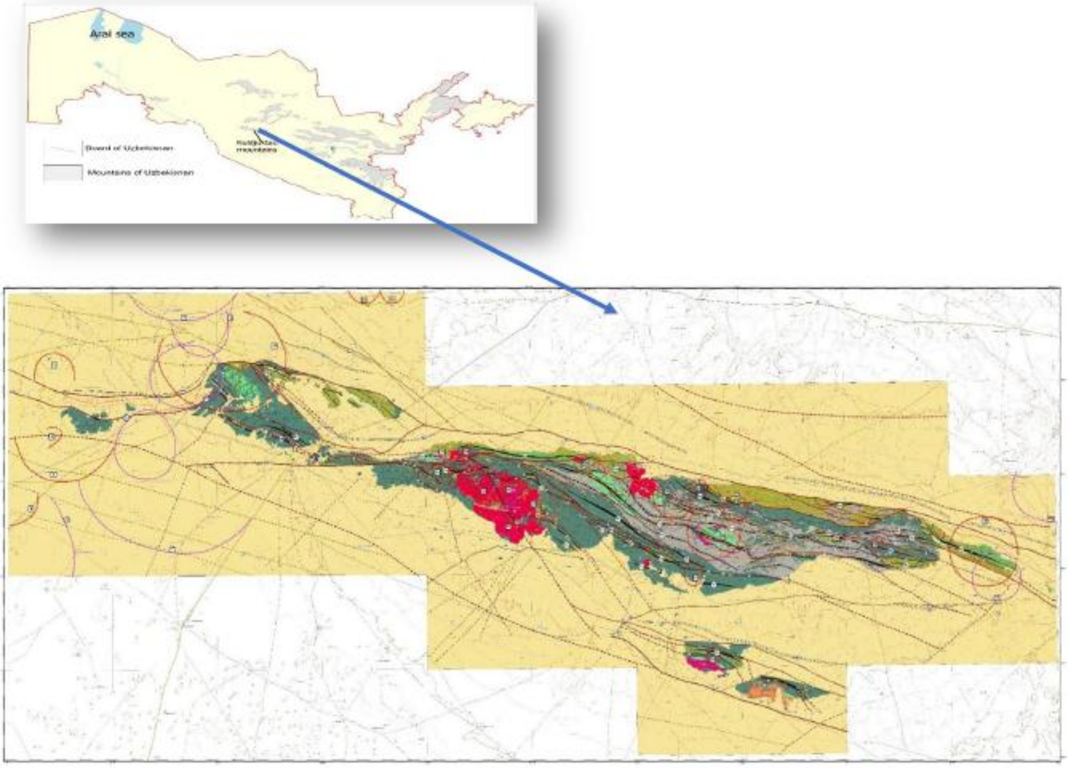

Fig. 1 Location diagram and electronic structural-formational map of the Kuldzhuktau mountains

Scale 1: 200000 in an ArcGIS environment.

In the basement, two structural stages are distinguished: the lower, Caledonian-Early Hercynian with a continuous section, up to 6000 m thick, composed of rocks of the Ordovician, Silurian, Devonian and Lower Carboniferous, and the upper, Late Hercynian, formed mainly by coarse clastic rocks of the Middle and Upper Carboniferous, 1100 m. The tiers are separated by regional disagreement.

The metallogeny of the Kuldzhuktau mountain massif was formed in the process of long-term geological development of Western Uzbekistan, as a result of intensive structural and material transformations of metal-bearing volcanogenic-sedimentary formations. According to RN Abdullaev, TN Dalimov and others [1], the description of the evolutionary development of the territory, confirmed by factual data, begins with the Ordovician formation of the Kitarmai-Yangob riftogenic structure.

The Taushan, Adylsai and Yangikazgan gold fields have been identified in the Kuldzhuktau mountain range. Despite the general similarity of their geology, they differ in the manifestation of magmatism and positions in relation to regional structures (Fig. 1).

The type of gold mineralization of the Kuldzhuktau mountains corresponds to the model of mesothermal deposits in the understanding of H.E. Frimmel, D.I.Groves [2]. According to their data, they were formed at a depth of 10-20 km, in the setting of an accretionary tectonic regime. The leading industrial type of indigenous gold in the world, the second most productive after

The Witwatersrand [3] are orogenic mesothermal deposits.

For deposits of the mesothermal orogenic type, there are many hypotheses of their formation: magmatogenic-hydrothermal, metamorphogenic-hydrothermal, sedimentary-hydrothermal, meteoric.

Recently, the theory of the metamorphogenic-sedimentary genesis of gold ore mineralization has been most widely developed, according to which, in the process of metamorphism, gold is carried out of rocks of the amphibolite facies by fluids along tectonic shear zones and is deposited among the overlying rocks of the greenschist facies.

The term "deposits of the orogenic mesothermal type" means a wide group of deposits and ore occurrences of gold, the main geological characteristics of which are shown in Table 1. Other names of this type of deposits in the world literature are mesothermal gold, metamorphic gold, gold-only, lode gold, shear-zone hosted, structurally-controlled deposits, greenstone-hosted, turbidite-hosted deposits.

For the formation of most of the Upper Phanerozoic mesothermal deposits, shear tectonics takes place. At the Taushan gold deposit in the Kuldzhuktau mountains, pre-ore deformation is caused by compression in the NE-SW direction, to the NNE, which caused the formation of fracture zones NW and sub-latitudinal directions, as well as small folds, ruptures and shear processes (northeast right-sided and east-north - eastern left-handed) [4]. These fractured zones were formed during compressional deformation caused by collision of tectonic plates. The sublatitudinal structural direction may partially reflect the sublatitudinal direction of the structural zone.

The insignificant deformation of the veins, and the close relationship of mineralization with lamprophic dikes, is the rationale for the fact that gold mineralization was formed during the collisional stage, controlled by a later phase of right-sided deformation of compression (NWD - SE) with significant strike-slip displacements along the faults. This could be related to the end of subduction, when fluids were released due to temperature equilibrium in subplate (accretionary) rocks associated with deep late metamorphism.

This assumption is based on insignificant deformation of the veins and the close relationship of mineralization with lamprophic dikes, which can serve as a good prospecting sign.

The primary gold ore occurrences of Kuldzhuktau can be subdivided into two formations: moderate gold sulphide and gold leaf quartz. The first is confined to gabbroid and granitoid intrusions and their exocontact zones. The ore-bearing system is a system of quartz veins of northeastern striking. Gold is closely associated with pyrite, arsenopyrite, sometimes with chalcopyrite, nickel sulfides, scheelite.

The gold-quartz formation within the Kuldzhuktau is confined almost exclusively to the sandy-shale deposits of the Taushan Formation (C_2), localized mainly at the nodes of intersection of faults in the sub-latitudinal and northeastern directions. An important ore-concentrating role is played by a northeast-striking fault, which is a hidden basement fault.

In the ore zones, veinlet and metasomatic silicification and quartz-carbonate - albite-sericite replacement (listvenite - beresite formation) are widespread.

In the predictive assessment of the territory of the Kuldzhuktau mountains, the indicated factors determining the ore content of the region were taken into account, in combination with direct signs of mineralization. Among the Statistical metallogenic analysis [5, 6] established high values of the spatial relationship coefficient: a combination of the following features: sand-shale rocks of the Taushan Formation (ni = 85%) 1+ nodes of intersection of sub-latitudinal and northeastern faults (ni = 60%) + wide development of veinlet silicification (ni = 100%) and metasomatites of the listvenite - beresite formation (ni = 70%) + porphyry - porphyritic dikes of the Late Permian complex (ni = 60%).

The most informative (ni = 70%) are combinations of "dikes and metasomatites" and "nodes of intersection of faults and metasomatites".

direct indicators was the establishment of gold in high concentrations in bedrock in crushers, furrow and ore samples, as well as in schlich and metallometric halos with identified sources of drift. Among the indirect signs, the increased concentrations of gold satellites were considered, first of all, As, Sb, Ag.

Below are the main factors affecting the localization of mineralization and proposed a geological prospecting model for gold deposits.

Intrusive formations make up about 15% of the area of the Kuldzhuktau mountains. In quantitative terms, granitoids and gabbroids sharply prevail among them.

Table No. 1

GEOLOGICAL FEATURES OF OROGENIC MESOTHERMAL DEPOSITS

Ore-bearing rocks	**Metamorphosed (from greenschist to granulite facies) volcano-plut.**	**Complexes, sedimentary rocks**
Ore-controlling structures	Regional tectonic faults, strike-slip zones	Examples of deposits Muruntau (Uzbekistan), Taushan (Uzbekistan), Kolar (India), Golden Mile, Kalgoorlie (Australia), Porcupine, Dome, Campbell Red Lake, Wal'd Or, Sigma (Canada), Berezovskoe, Sukhoi Log, Olympiada (Russia), etc.
Age	Archean to Phanerozoic	
Morphology	Vein bodies of various morphology, vein zones, sheet-like bodies and deposits	
Metasomatic changes	Carbonation, sulfidization, sericitization, alkaline metasomatism	
The main minerals are	Quartz, calcite, dolomite, ankerite, feldspars, actinolite, sericite, etc.	
Typomorphic minerals Типоморфные минералы	Pyrite, pyrrhotite, magnetite, chalcopyrite, galena, sphalerite, arsenopyrite, scheelite	
Au:Ag	10: 1 and 5: 1, sometimes 1: 1	
Fineness Au	750-990	
T-P conditions of the ore process	mean values: temperature 350-250° C and pressure 1-3 kbar; minimum values: temperature 150° C and pressure 0.5 kbar; maximum values: temperature 700° C and pressure - more than 5 kbar	
Depth of formation	10-20 km	

According to the conditions of formation, they correspond mainly to the mesoabyssal facies of depth. Volcanogenic formations are noted in the Ordovician, Early Silurian and Middle Carboniferous deposits.

Effusives and tuffs of the Ordovician and Early Silurian correspond to the basalt-andesite-liparite group of formations, and were formed in the geosynclinal stage of development against the background of incipient uplifts.

The formational appearance of volcanics is consistent with their formation in the inversion stage in the most stressed areas, which experienced a tendency to uplift, from the Middle Ordovician Early Silurian effusive volcanogenic formations.

The most complete characterization of the Kuldzhuktau granitoids was given by E.P.Izokh et al. (1975), who distinguished two intrusive series: the Koshrabad gabbrosyenite-granite (D_3-C_1) and the Kuldzhuktau gabbro-granite (C_3-P_1) [7].

The Tazazgan graphite-nickel-cobalt deposit is associated with the Kuldzhuktay intrusion of the peridotite-norite-gabbro formation, which belongs to the belt of mafic-ultramafic rocks of the zone. Dissected disseminated pyrrhotite-chalcopyrite-pentlandite ores with a thickness of about 20 m with a nickel content of 0.3-1.5% [8].

Based on the analysis of the petrochemistry of the ultrabasite-basic massifs of Western Uzbekistan, R. Akhundzhanov et al. (2014) concluded that the magmatic melts of the ultramafic-basic intrusions of the Kuldzhuktau Mountains have a separate origin of the magma source and a distinctive ore content from other such massifs in Western Uzbekistan [9]. The source of magmas here is deeper. Based on this, it follows that the basic-ultrabasic rocks of the Kuldzhuktau Mountains have a different genetic branch, which is combined in the zone of the Trans-Asian lineament (I.Kh.Khamrabaev, 1991) [10].

Analysis of the material indicates that the intrusive complexes belong to the Hercynian tectonomagmatic cycle, mainly to its orogenic stage with a conditional subdivision into two stages: consolidation (C_3-P_1) and postconsolidation (P_2).

Feature magmatism of this time indicates a significant degree of consolidation of structures (layered peridotite - norite - gabbro intrusions, nepheline syenites, carbonatite-like formations, increased potassium content of granitoids and the presence of subalkaline varieties among them).

The upper Carboniferous gabbroid complex composes the Beltau intrusion and participates in complex multiphase massifs - Taushan, Shaydaraz, forming independent bodies in them. Separate small stock-like bodies can be traced along the northern elephant of the Kuldzhuktau mountains (the area of the Darvaza and Koshshak heights).

The complex is characterized by a distinct layering of the Beltau massif, the Shaydaraz and Taushan intrusions, the presence of hyperbasites of the basaltoid series in them, the genetic relationship with it of complex copper-nickel-graphite mineralization (the Taskazgan deposit and a number of ore occurrences), the presence of rare-metal-carbonate-like rare-earth-carbonate-like rare-earth-carbonate rocks in the Beltau intrusion.

The Beltau intrusion is located in the northwestern part of the Kuldzhuktau mountains, confined to the syncline, complicating the southern wing of the North Beltau anticlinal structure. In plan it is oval in shape, elongated in the north-west direction for 6 km with an average width of 1.5 km.

The Shaydaraz intrusion is located on the southern slope of the central part of the Kuldzhuktau Mountains (between the Aktosty and Shaydaraz Kolts). Occurs in the nuclear part of the Taushan anticline. It breaks through the sandy-shale deposits of the Middle Carboniferous in part. Intrusive is a lenticular body elongated in the southeastern direction (width 1-1.5 km, length 12 km) with steeply dipping contacts. Gabbroids are cut by small stocks and dike bodies of granitoids of the Early Permian complex.

The Taushan intrusion is essentially the southeastern continuation of the Shaydaraz massif. It is confined to the nuclear part of the Taushan anticline, composed of Lower Devonian limestones, on the wings - terrigenous deposits of the Middle Carboniferous. Granitoids are distributed mainly in the marginal parts and form a large outcrop in the central part. The intrusive is a slightly eroded narrow (0.5-1.0 km) stock-like body with an area of 4 km^2, elongated in the north-west direction up to 5 km.

The study of thematic parameters of the relationship of gold mineralization with the structural elements of the region shows that among the variety of ore-controlling structural factors, meridional - transverse faults are of great information value.

According to our field observations, it was established that the Taushan ore field includes a series of NNE and NE quartz veins.

Table No. 2
INTRUSIVE COMPLEXES OF KULDZHUKTAU MOUNTAINS
Compiled by Razikov O.T., Maripova S.T. according to I. Kh. Khamrabaev, V.V. Baranova, A.I. Egorova, E.P. Izokh, A. Kayumova, K. M. Kromskoy and others.

Age	Cycle	Stage	Intrusive complex	Main petrographic rock types (in age sequence)	Intrusives, morphology and sizes of intrusive bodies	Associated mineralization
P_2		Postorogenous (postconsolidation)	Porphyry-porphyritic	Trondhjemite-porphyry, tonalite-porphyry, diorite-porphyrite, diorite, diorite-porphyrite, spessartite	Dykes of small thickness and length, Tozbulak dike field	Zolotorudnaya
P_1?			Nephelin-syenite (265 millen years)	Aegirine-augite, ferrogastingsite, lepidomelane-ferrogas-tingsite, nepheline syenite. Dyke facies: pegmatites of nepheline syenites, albitites.	Stock-like bodies, Tozbulak intrusion, Tuzkoy stock	Rare metal rare earth
P_1		Orogenic	Granitoid (270-280 millen years).	Two-mica and tourmalinized granites Dyke facies: aplites, granite pegmatites	Stock-like bodies Tozbulak, Ayakguzhumdinsky	Tin rare-earth-rare metal
C_3-P_1		Earlyo-genic Postin-Versioned	Syenitodiorite (280 million years)	Quartz biotite syenite-diorite syenite-diorite, amphibole syenite, nordmarkite, granosyenite and alkaline granite Dyke facies: aplites	Stock-like bodies Tozbulak and Kyngyr-Tau (thickness 5-25 m)	Polymetal personal
C_3	Hercynian		Gabbroic (290-310 million years old))	Augite and hornblende gabbros, gabbrodiorites *, gabbronorites, troctolites, plagioherzolites	Lopolitic and stock-shaped bodies Beltau, Shaydaraz-ky, Taushasnsky	Copper-nickel-graphite, gold ore
				Dyke facies: Labrodorites, microgabbros, microdiorites, diabase porphyrites	Thickness 0.2-2m, length up to 500m	

* Intrusives of peridotite - norite-gabbro complex - layered, most of their composing rocks, with the exception of dykes, belong to the same intrusion phase. Gabbro - diorite and rocks similar to it in composition are products of the contact impact of granitoid intrusions.

The bedding planes outgoing to the surface are intersected by steeply dipping veins in three main directions:

veins of north-north-east striking (10^o-33^o) associated with echeloned right-sided fracture systems;

veins in the east-north-east direction (60^o-80^o) connected with a system of echeloned cleavage cracks;

veins of northeastern striking (40^o-50^o) associated with tension cracks.

This is consistent with the mesothermal conditions of the formation of quartz veins. Some of the finer quartz veins and veins are siderite edged. They form echelon-like left-sided series of SV (41-50 °) strike.

To the south of the Taushan deposit to the Geochemical ore occurrence, the structures are noticeably changed along the strike of the beds from north-north-west and north-west to sub-latitudinal direction. It is supposed to control mineralization by NNE fractures of the second order trending in relation to the sublatitudinal right-sided shear zone of the first order.

The primary role in the formation of the field is played by a steeply dipping fault of a near-meridional orientation - it is both a controlling and enclosing structure; the west-north-west fault with a south dip is an ore-localizing structure.

At the Taushan deposit, the transverse structure is quite clearly manifested - it is an extended fault in the north-northwest direction, accompanied by subparallel folding. The fault contains pre-ore dikes and gold bodies. At the Adylsai deposit, located southeast of Taushan, the transverse fault is not clearly manifested, it is smaller both in length and thickness. This entire transverse structure is saturated with late dikes and contains gold mineralization.

At the Yangikazgan deposit, located east of Taushan, riverine structures are not manifested at all. The position of this object is determined by the intersection of longitudinal, west-north-western and thin east-north-eastern faults.

If we consider the Taushan-Adylsai-Yangikazgan trend and analyze the patterns of distribution of gold occurrences in this territory, a decrease in the tectonic development of ore-bearing structures, a decrease in their saturation with pre-ore dikes, and a decrease in the intensity of metasomatic processes are clearly manifested. The productivity of gold mineralization decreases in the same sequence.

The density of gold mineralization in the Taushan and Adylsai ore fields is higher than in the Yangikazgan. In Taushansky and the Adylsai ore fields, the identified gold objects are located in fractures in three directions, and in Yangikazgan, gold objects with high gold contents are concentrated mainly in sublatitudinal and west-northwestern faults.

For all objects, the deposits of the Taushan Formation are host to gold mineralization. However, if we consider the position of gold mineralization from the top of the underlying Devonian limestones, it is established that in the Taushan ore field it gravitates towards the bottom of the formation section, which consists of a stratum characterized by a fine-grained composition. The gold mineralization of the Adylsai and Yangikazgan ore fields, on the contrary, is confined to the middle and upper parts of the section of the formation and is composed of horizons and members of rather heterogeneous properties. In the section, there is a wider development of interformational faults in the west-northwest directions, which play an important role in the localization of mineralization.

The ore-formational type of mineralization is gold-quartz and gold-sulfide-quartz veinlet metasomatic.

In relation to the processes of ore deposition, metasomatites are divided into pre-ore (propylites, skarns), pre-ore (beresites, listvenites, gumbeyites, greisens, etc.) and syn-ore (monomineral, non-zonal).

At the studied deposits and ore occurrences, metasomatites of the berezite facies are mainly developed. It is known that beresites are formed as a result of low-medium-temperature acid metasomatism over felsic and intermediate igneous rocks, terrigenous rocks and products of their metamorphism. Beresitization is one of the most common metasomatic transformations and is known in connection with the deposits of Au, Ag, U, Mo, and base metals.

Table No 3

PREDICTIVE SEARCH MODEL OF GOLD MINER IN THE KULDZHUKTAU MOUNTAINS (Western Uzbekistan)

(compiled with the use of materials by I.Kh.Khamrabaev, Kh.R. Rakhmatullaev, I.M. Golovanov, etc.)

Criteria	Characteristic
Lithological-stratigraphic	Deposits of the Taushan Formation, Middle Carboniferous-schists, metasandstones. Contacts of favorable lithological horizons with screening rocks - up to Devonian-Carboniferous carbonate strata.
Magmatic	Dyke beams, zones and belts within metamorphosed sedimentary-volcanic, terrigenous and granitoid formations.
Structural	Systems of long-term development of deep-seated faults of the linear type, accompanied by zones of shearing and shearing. The area of bend and intersection of fault zones with deep faults and transverse (northeastern) strike. Mineralizing faults of the northeastern, less often northwestern directions.
Geochemical	Regional geochemical anomaly of gold, silver, arsenic (more than 2-3 clarkes) in sedimentary-metamorphic rocks, magmatic formations with high concentrations near faults. Elevated background gold contents in igneous rocks, sedimentary-metamorphic rocks with clarke gold. High contents of gold in antimonite and cinnabar, abnormal contents of arsenic and mercury in bedrocks.
Metasomatic	Metamorphic greenstone belts (associated with regional metamorphism of the kyanite-andalusite facies). Graphitization of sedimentary-metamorphic and igneous rocks.
Geophysical	Gravitational and magnetic fields. In closed areas, granitoid intrusions are mapped by weak negative gravity anomalies, and their productive exocontact areas are mapped by weak positive local magnetic anomalies, and gold deposits are out of local anomalies of gravity and magnetic fields.

Composing beresites, the main minerals are quartz, muscovite (sericite, phengite, illite, less often paragonite), carbonates (depending on the original host - dolomite-ankerite, calcite, magnesite-siderite), chlorite (with wide variations in composition), pyrite. Having established the time of the formation of beresites, we can confidently say that the time of their formation corresponds to the ore process itself.

Based on general geological data, it can be assumed that the gold ore occurrences are paragenetically related to porphyry-porphyrite dikes. The most likely source of antimony and mercury is deep-seated. Possibly basaltoid. Judging by the geochemical data, the middle parts of the ore column were exposed. And the main elements of indicators are Au, Ag, As, Sn, Zn, W, Pb, the clarke content of which exceeds several times. The most informative were the halos of gold and arsenic, as well as halos of silver.

Thus, for the gold mineralization of the Kuldzhuktau mountain range, the following conclusions were obtained:

1. The ore-bearing for gold are deposits of the Taushan Formation, which are volcanic-siliceous-terrigenous (flysch-stromic) C_2 formation. Considering that the Kamysta Formation belongs to this formation, it can also host gold or paragenic mineralization.

2. Prospective areas for gold mineralization may be those areas, the position of which is determined by the meridional north-northwest ore-controlling faults. They are accompanied by subparallel plicative forms, localize zones of organizing, and contain late dikes. The prospects of the site increase the higher its overall fragmentation, which is greater if there are diagonal breaks in the east-north-east orientation. These conditions are met by areas located in the central and western part of Kuldzhuktau and gravitating towards the zone of powerful north-north-western

structures. Of these structures, the most favorable ones are accompanied by halos of metasomatic alteration of terrigenous rocks - beresitization and listvenitization.

3. Gold mineralization is paragenetically associated with a complex of small intrusions and dikes. They were most developed in the central part of the mountains and on the western flank, where a dike field of northeastern orientation is recorded in the Tozbulak granitoid massif.

4. The leading types in the Kuldzhuktau mountain massif are gold-quartz, gold-sulfide-quartz industrial types of ores, by morphology vein and vein-veinlet (in the granitoids of the Tozbulak massif).

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