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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

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GEOLOGICAL AND GEOCHEMICAL MODELS OF GOLD STOCKWORK DEPOSITS IN INTRUSIVE PLUTONS OF NORTH AND EAST KAZAKHSTAN

Abstract. The objective of this studying is identifying the gold mineralization and associated elements in gold-bearing stockworks of gold-sulphide-quartz type large deposits in Northern and Eastern Kazakhstan; detecting geological and structural position of the ore stockworks.

Complex compounds of silver and gold with tellurium have been revealed in the Sekisovskoye and, with tellurium and bismuth in ores of the Vasilkovskoye deposit. The complexity of ores involves setting a versatile task of basic and trace elements recording during all stages of work: from geological evaluation to production exploration. Modern processing technology and the latest development techniques allow classifying those fields as objects of industrial development priority. Studying them has scientific significance in the matters of endogenous ore formation, and creates a prerequisite to identifying promising new areas and deposits, both in Kazakhstan and in other parts of the world.

Key words: gold deposit, intrusion, stockwork, tellurides, bismuth, Kazakhstan.

History of formation and geodynamic evolution of CA is considered in numerous works [1-3].Recent researches proved that Late-Paleozoic shearing deformations are dominant in the structure of Central Asia. They complete formation of orogenic collage of terrains formed in the period of late Devonian - Early Carbon when Kazakhstan (Kazakhstan-Baikal) composite continent collided with Siberian one. FurtherduringLateCarbon-Permiantherewasconvergenceandcollisionof East-European, Kazakhstan-Baikaland Siberiancontinents[4-8].

Itcaused widely spread collision metamorphism and magmatism and on the whole it caused consolidation of earth crust and formation of compound continent basement.

Thetestingsiteconsideredinthearticle (Rudny Altaimetallogenic zone, Sekisovskoye deposit) refers to north-west sector of Central-Asian mobile belt. Itstectonicstructureandevolutionwerecharacterizedin [9-11].

VasilkovskoyedepositwasformedwithinKokshetauterrain, locatedinstructuralLower Paleozoic collage of Central Kazakhstan to the west and the north west direction from Torgai-Middle- Tien Shan microcontinent. The territory is comprised into Kokshetau-North –Tien-Shan early Paleozoic orogenic belt consisting of some suture zones with fragments of collision and transform sutures. Most terrains represent rubbles of ancient continent (more likely Rodinia). TerrainsdifferfromeachotherbyfaciesofRiphean-LowerPaleozoiccover [1, 12].

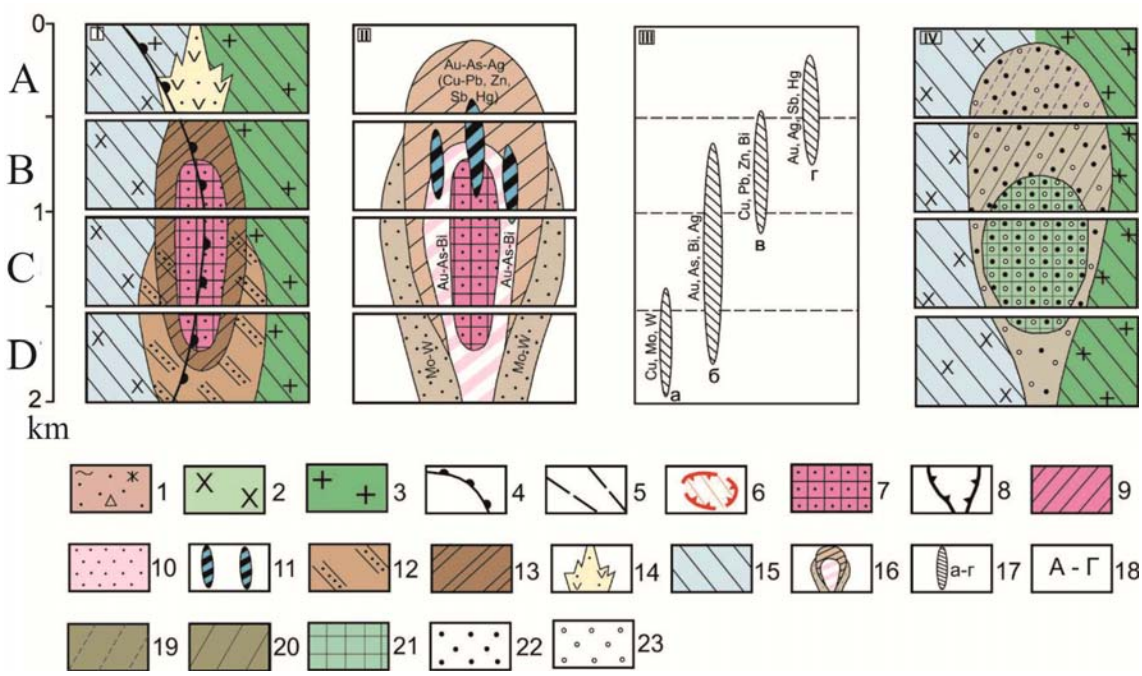
Deposits associated with mesothermal plutons of increased basicity (Sekisovoye) and alkalinity (Vasilkovskoye) have been studied.

These deposits were formed in a large mining regions of Kazakhstan. They are represented by gold-bearing stockworks and breccias (with gold contents from 1x n to 10xn g/t) and have a high raw material potential, with the prospects of increasing reserves to depth and along the flanks within the predicted mineralized zonesThe ores are characterized by a variety of gold tellurides, silver, and bismuth minerals.

Geological and geochemical model of the Vasilkovskoye deposit. The Vasilkovskoye gold field is localized at the intersection of Dongulagash and Vasilkovskoye-Berezovka Faults; it has a frame-block tectonic structure and contrasting hydrothermally altered rocks.

The Vasilkovskoye deposit is associated with the contact of gabbro-diorite and diorite with hornblende-biotitegranodiorite and plagiogranites. The cross section of the stockwork on the surface is the first hundreds meters; the vertical strike is up to 1.0-1.5 km. The average gold content is 5.3 g/t. The stockwork consists of a series of gold-bearing ripples bent at the angles of 35-40 in the south-west direction [1, 13].

The deposit is characterized by concentric metasomatic, mineral, and geochemical zoning.Local hydrothermal alterations (kalifeldsparization, beresitization, silicification, albitization, chloritization etc.) are developed in the rocks of the Vasilkovskoye deposit. The local pre-ore kalifeldsparization is presented by series of sub-parallel zones of veins and veinlets of feldspar and quartz-feldspar composition. This generation of kalifeldspath is developed at most in the axial part of the stockwork. The ore in such areas often takes pegmatoid appearance (figure 1). A syn-mineral microcline is framed by gold-bearing quartz-arsenopyrite veins and arsenopyriteveinlets in the form of hems and ribbons up to 1-5 cm [1, 14]. It is most likely that the most recent derived kalifeldspath forms thin (0.1-0.5 cm) winding, threadlike punching, intersecting quartz-arsenopyrite veins, lenses and bonnies. Interspersed gold-bismuth-pyrite-arsenopyrite-quartz mineralization is associated with kalifeldspaths.



Legend: 1 – Clayey – rock debris weathering crust; 2-3 – Intrusive rocks of O_3-S_1 (Zerendinsky complex): 2 – Undivided gabbro-diorites, diorites; 3 – Granodiorites, Plagiogranites; 4 – Contact between rocks of intermediate-basic (gabbro-diorites,diorites) and acid composition (granodiorites, granites); 5 – Faults; 6 – Boundary of vein and vein-disseminated gold mineralization; 7 – Gold-bearing stockworks; 8 – Boundary of gold-bearing stockwork in section; 9-10 – Grades of gold in gold-bearing stockwork: 9 – Medium and high, 10 – Low; 11 – Gold-polymetallic ore bodies; 12-15 – Hydrothermally altered rocks; 12 – K-feldspathic altered rocks, 13 – Beresites, 14 – Albite-chlorite metasomatites, 15 – Propylites; 16–Geochemical zones, 17 – Element associations: a – lower-ore Co-Mo-W, 6 – productive Au-Bi-As-Ag, c – upper-ore polymetallic Cu-Pb-Zn-Bi, d – supra-ore-upper-ore As-Ag-Sb-Hg; 18 – Zones of different erosional level: a – frontal (supra-ore), b – near-frontal (upper-ore), c – intermediate (middle-ore), d – root (lower-ore-sub-ore); 19 - arsenopyrite mineralization with chalcopyrite, galena, sphalerite, faded ore and antimonite; 20 - arsenopyrite mineralization with the appearance of late sulfide-polymetallic with antimonite; 21 - arsenopyrite-bismuth mineralization; 22 - weakly gold-bearing hyppidiomorphicarsenopyrite; 23 - porphyroblastarsenopyrite.

Figure 1 – Model of metasomatic (I), geochemical (II, III) and mineralogical (IV) zoning of the Vasilkovskoye gold deposit (accodingRafailovich M.S. with authors additions)

Beresite halo is several times the size of the ore stockwork. Beresites (quartz, sericite, muscovite, carbonate, chlorite, pyrite, arsenopyrite) are placed in the section above the kalifeldspaths. Two mineral assemblages are combined in them: an early interspersed gold-pyrite-arsenopyrite-quartz vein and a recent veined gold-quartz-polymetallic (native gold, quartz, fahlore ore, tellurides, galena, tetradymite). Maximum productive gold mineralization is localized in the areas of beresites and kalifeldspaths overlap combination. Chlorite-albitemetasomatic rocks are developed upslope of the ore-bearing structures for hundreds of meters [15, 16].

Gangue minerals (quartz, carbonate, tourmaline, sericite, fluorite) are widespread; they form typical relationship (correlation, proportion, ratio, relation, relationship) with ore-metasomaticbodies.En echelon, subparallel, intersecting veins and veinlets of the ore stage, with characteristic fine-grained dark gray quartz with sulfides and native gold, build up the basis of stockwork. The largest (capacity of up to 0.5-1.0 m) gold-bearing veins expand extend in the stockwork frontal zone. Postmineralformation are presented by calcite-quartz-sericite, carbonate-fluorite, quartz-tourmaline-epidote and carbonate-aedelite associations.The veins, veinlets and bonnies of calcite-quartz-sericite composition are common in medium and upper horizons; a quartz-tourmaline association is located in the uppermost part of the deposit; fluorite is in the root part; a carbonate-epidote-aedelite association edges the gold stockwork [17].

There are early and recent mineral associations [16, 17]. The early association is pyrite-pyrrhotite-marcasite-quartz; actual ores are gold-pyrite-arsenopyrite-quartz (with pyrrhotite, loellingite, chalco-pyrite), gold-bismuth-pyrite-arsenopyrite-quartz (molybdenite, scheelite, cubanite, native bismuth, bismuthine, tetradymiteheterochronousfahlore ore); and gold-polymetallicassociation (with chalcopyrite, sphalerite, galena, tennantite).

Mineral zoning is manifested at the level of paragenetic associations and particular minerals. Pyrite-pyrrhotine-marcasite-quartz association is developed mostly in medium and deep horizons; gold-pyrite-arsenopyrite-quartz and gold-bismuthine-pyrite-arsenopyrite-quartz perform a blocker zone (B and C); gold-polymetallic and quartz-carbonate-antimony bloom-fahlerz one is at the upper horizons [17]. Figure 1 presents a modernized model of the geological and geochemical zoning of the deposit.The main indicator elements of the deposit are Au, As, Bi (the contrast is hundreds or thousands of abundance ratio), are less contrasting are W, Sb, Ag, Cu, Pb, Hg (units or the first (a few) tens of abundance ratio), weak contrasting are Zn, Mo, Ni, Co , Cr, Mn (units of abundance ratio) [14].

Gold is a subjacent element with a polymodal distribution of concentrations; its content is equal to the average (in g / t) in wallrocks - 0.37, ore zones - 1.0, orebodies - 3.7, ore columns - more than 10 [13]. The mean and high content of gold is at the central part of the ore-bearing stockwork, the low content is at the periphery. The content of As is from 0,0n to 8.5%: in disseminated ores it is 0.01-0.1%f, in stringer-porphyry mineralization it is 0.3-1.0%; in vein ores it is 0.5-2.0%and more.

The recent association is quartz-carbonate-antimony bloom-fahlerz. Pyrite and arsenopyrite (95-98%) are common in all the associations, but they are mainly concentrated in gold-bearing quartz veins and veinlets. Arsenopyrite makes veins, rosette and pectinal formations, lentil and nodular splashes, irregular impregnation in quartz and hydrothermally altered rocks. Arsenopyrites contain Au (up to hundreds of mg / t), Ag (5-50 g / t), Bi (up to100-300 g / t), Pt (0,3-0,5 g / t), Cu, Pb, Zn, Co (up to 0,01-0,1%), Mo (up to 20-50 g / ton).

The structure of the ore field, the location of mineralization, endogenic, geochemical, and mineralogical zonation give the reason to believe that the prospects for the object have not been fully revealed. Special attention should be paid to the sites located to the south-west of the deposit, where deep-lying ore bodies can be found.New ore bodies, such as linear zones of vein-disseminated mineralization, can also be found to the north-west of the Vasilkovskoye deposit

Geological and geochemical model of the Sekisovskoye deposit.The Sekisovskoye deposit area is located within the Aleysk subzone in the Rudnoaltayskaya structural-formational zone. The deposit is located within the Shemonaikha-Narym lineament allocated according to space images deciphering, and is located in the inner north-western part of the Sekisovskoye ring structure The ore field of the Sekisovskoye deposit is localized within the multiphase gabbrodiorit-diorite-granodiorite-granite Sekisovskoye massif at Zmeinogorsk collision complex[1, 18, 19].

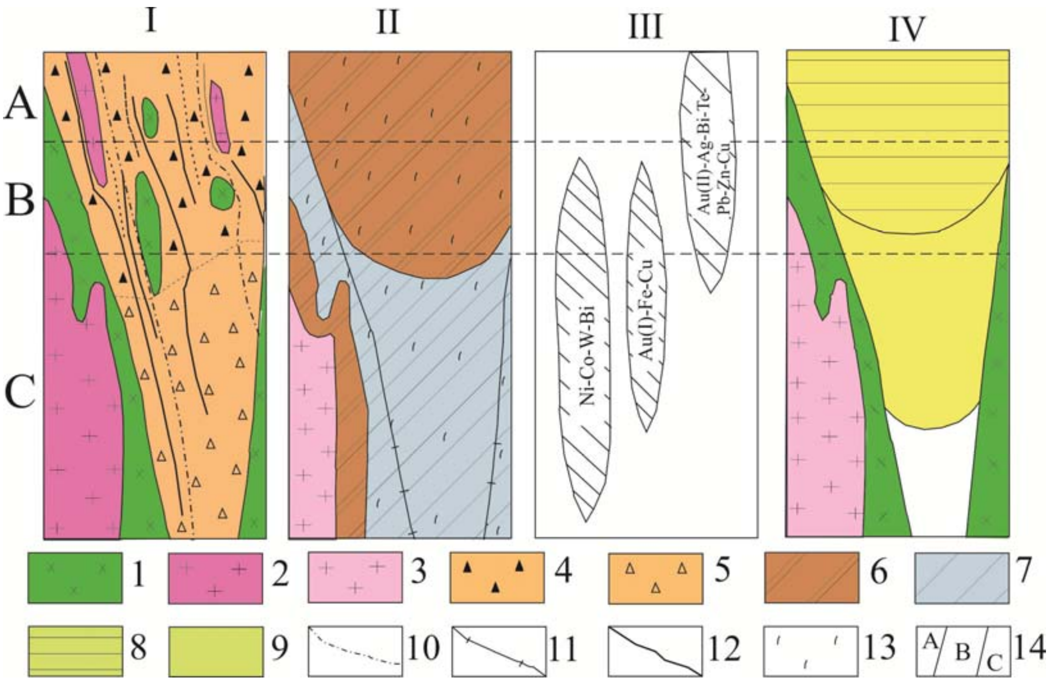
Ore-bearing rocks at the deposit are breccias of tubular, elongated shape with the sizes from 40x100 meters to 120x500 m. Their traced depth exceeds 950m. There are two points of view on the genesis of the breccias. According to one point of view, they are magmatic rocks, according to the other, which is shared by most researchers, they are explosive-hydrothermal rocks [20].

The ore-bearing explosive breccias are composed of fragments of magmatic rocks (diorite, plagiogranites and transitional differences between them) cemented by finely divided material either of the same or of veined composition (quartz, quartz-carbonate bonnies and veins with inclusions of ore minerals - pyrite, sphalerite, galena, with the predominance of the first one) [13, 20].

The breccias are cemented with ground, hydrothermally altered rock material with quartz-sericite-chlorite composition interspersed with sulphides (mainly pyrite), with rare inclusions of rock buttes.The sulphide content in the cement of the breccias is irregular and varies from fractions of a percent to 15%, on average 5%. Gold mineralization is spatially and genetically associated with sulfides [14].

The gold is unevenly distributed and forms a kind of nest- ripple type of mineralization. Higher concentrations of gold occur where different types of breccias are in contact as well as the breccias are in contact with the host diorite and felsic dykes. Four mineralized zones are distinguished in the breccias, each of which contains a group of ore bodies.Five mineralized gold zones are distinguished at the deposit, each of which contains a group of localized ore bodies [16].

Two mineral parageneses are developed in primary ores. Gold-iron-copper- rare metals paragenesis (gold I, quartz, magnetite, pyrrhotite, marcasite, pyrite, scheelite, bismuthine, molybdenite, chalcopyrite) is characteristic for the early breccias (at medium and deep levels) (figure 2).



*Legend:*1 –diorites, quartz diorites; 2 – granodiorites, plagiogranites; 3 – unchanged granodiorites; 4 –breccia mixed type mixed breccias;5 – breccias of gabbro-diorites, diorites; 6 – berezitization; 7 – propilization; 8 – late stage of the mineralogical association: native gold, tellurium, silver, quartz, carbonate, chalcopyrite, altaite, antimonite, tennantite, galena, sphalerite; 9 – early stage of the mineralogical association: gold-quartz-magnetite, pyrrhotite, marcasite, pyrite-scheelite, bismuthin, molybdenite, chalcopyrite; 10 – dikes basic and acidic composition; 11 – boundaries of ore stockwork; 12 – ore veins; 13 – carbonatization and silicification;14 – horizons A – upper, B - medium, C - deep.

Figure 2 – The model of ore, metasomatic, geochemical and mineralogical zoning of the Sekisovskoye deposit

At a later stage of a mixed-type breccia formation a gold-silver-bismuth-telur-polymetallic (gold II, native silver, tellurides, quartz, carbonate, pyrite, chalcopyrite, altaite, aykinitom, tennatitom, galena, sphalerite, greenockite, tellurovismutinom, petzite, hessite, kreneritom, calaverite, sylvanite) association formed at the upper levels of breccia bodies.This association is controlled by dykes of quartz albitophyres, granite porphyries and felsites [13]. Quartz carbonate and quartz sulfide veins predominate. Gold is found as free metal, tellurides, finely-dispersed impurities in sulfide.Free gold has dendritic, acicular and octahedral forms.

Gold is the main admixture in pyrite. The increase of its concentration is accompanied by an increase of the number of its main satellites - Ag, Bi, Pb. It forms microinclusions in pyrite, and also along cracks and on the contact of grains. Splices of gold were found with tellurides of silver (hessite, petzite).

Inalltypesofbrecciadecreaseofgoldconcentrationto thedepth(in 2.5 – 6 times)isnoted.Ore bodies in volume represent steeply dipping geochemical ripples.

The most productive horizon for the deposit is from +320 m up to -40 m. There is the increasing tendency for ore densification into depth from east to west. Coincident projection of ore-geochemical ripples show plunge of ore-geochemical pillars. This implies practical conclusion about possible new ore pillars deeply embedded at west flank of the deposit. East flank of the deposit is evidently of little promise.

Conclusion. General regional criteria of large-volume gold-ore stockworks in intrusive plutons (on the example of deposits Vasilkovkoye and Sekisovkoye). These criteria can be used for dividing intrusive stockworks into ore and barren at different stages of geological exploration: deposites were formed at mesothermal depths into collision stage of intraplatemagmatismactivization; models of metasomatic zoning are characterized by hydrothermal processes large scale both in space and time; there are ore-control morphostructures of complex structure (suture zones, folding zones, ring deformations and others);

The following is characteristic for large-volume gold-ore stockworks in intrusive plutons (on the example of deposits Vasilkovskoye and Sekisovskoye):confinedness of ore to explosive breccias; anomalous geophysical fields; confinedness of ore to multiphase intrusive masses of basic (Sekisovkoye) or alcaline compound (Vasilkovskoye) of I-S type; wide-spread occurrence of differentiated dike complexes with aplite and pegmatite bodies; active occurrence of enclosing rocks metamorphism and single hydrothermal alteration (propylitization, beresitization, kalifeldsparization, albitization, chloritization); several generations of free gold; geochemical specification Au; As (excluding Sekisovka); Bi; Te; W; Cu; zonal structure of stockworks (on the top - veined, veined and veinlet-disseminated ores, at medium and lower horizons - vein and impregnated ores; the following is characteristic for large gold-sulphide and gold-quartz objects:the process of forming ore bodies prolonged up to hundred million years on the background of changing geodynamical conditions and sources and mechanism of gold transition and concentration; location of large and huge gold reserves when its content is rather low.

Within Kazakhstan, similar complexes were formed over 600 million years from the late Riphean to the Quaternary. The most productive stages for gold are O3; D_{1-2}; C and K.

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СОЛТҮСТІК ЖӘНЕ ШЫҒЫС ҚАЗАҚСТАНДА ИНТРУЗИВТІК ПЛУТОНДАРЫНДАҒЫ АЛТЫНКЕНДІ ШТОКВЕРКТІК КЕНОРЫНДАРДЫҢ ГЕОЛОГИЯ-ГЕОХИМИЯЛЫҚ МОДЕЛДЕРІ

Аннотация. Мақсаты – алтынкенді минерализацияның және қосымша алтынды штокверк элементтері бар Солтүстік пен Шығыс Қазақстанның сульфидті-кварцтық типті ірі алтын кен орындарының жүйелі орналасуын табу, штокверк кен орындарының геологиялық-құрылымдық орналасу жүйесін анықтау.

Алтын мен күмістің теллурмен (Васильковский кен шығару орны) рудадағы күрделі қосылуының кең дамуы анықталып отыр. Рудалардың кешеніндiлiгi жұмыстың барлық кезеңдерін, геологиялық-бағалаудан бастап қолданулық барлаудықоса алғандағы жұмыстарды жүргізу кезінде негізгі және бағыттас компоненттердің жан- жақты есебінің иіндетін қоюды бағамдайды. Кен байытудың заманауи технологиялары, өңдеудің жаңа тәсілдері қазіргі кезде бұл кен орындарын бірінші кезектегі өнеркәсіптік игеру обьектілеріне жатқызуға мүмкіндік береді. Оларды зерделеу эндогендік кенжаралу мәселелеріне ғылыми маңызды және Қазақстанда, сондай-ақ әлемнің басқа да өңірлерінде жаңа перспективалық алаңдар мен кен шығатын орындарды анықтаудың алғыштарын туындатады.

Түйін сөздер: алтын кен орны, интурзия, штокверк, теллуридтар, висмут, Қазақстан.

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ГЕОЛОГО-ГЕОХИМИЧЕСКИЕ МОДЕЛИ ЗОЛОТОРУДНЫХ ШТОКВЕРКОВЫХ МЕСТОРОЖДЕНИЙ В ИНТРУЗИВНЫХ ПЛУТОНАХ В СЕВЕРНОМ И ВОСТОЧНОМ КАЗАХСТАНЕ

Аннотация. Целью исследования является выявление закономерностей распределения золоторудной минерализации и сопутствующих элементов в золотоносных штокверках крупных месторождений золото-сульфидно-кварцевого типа Северного и Восточного Казахстана, определение геолого-структурной позиции рудных штокверков.

Выявлено широкое развитие сложных соединений золота и серебра с теллуром, (месторождение Секисовское), с теллуром и висмутом в рудах (Васильковское месторождение). Комплексность руд предполагает постановку задачи разностороннего учета основных и попутных компонентов при проведении всех стадий работ: начиная с геолого-оценочных до эксплуатационной разведки. Современные технологии обогащения, новейшие способы разработки позволяют сейчас отнести эти месторождения к объектам первоочередного промышленного освоения. Их изучение имеет научное значение в вопросах эндогенного рудообразования и создает предпосылки выявления новых перспективных площадей и месторождений как в Казахстан, так и в других регионах мира.

Ключевые слова: месторождение золота, интрузия, штокверк, теллуриды, висмут, Казахстан.

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