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GEOLOGICAL AND STRUCTURAL FEATURES, MAGMATISM AND MINERALIZATION OF SEKYSIVSKE AND VASYLKIVSKE STOCKWORK GOLD DEPOSITS (KAZAKHSTAN)

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ГЕОЛОГО-СТРУКТУРНІ ОСОБЛИВОСТІ, МАГМАТИЗМ І ЗРУДЕНІННЯ СЕКИСІВСЬКОГО ТА ВАСИЛЬКІВСЬКОГО ШТОКВЕРКОВИХ РОДОВИЩ ЗОЛОТА (КАЗАХСТАН)

Purpose. Identifying gold mineralization and associated elements distribution patterns in gold-bearing stockworks of large deposits of gold-sulphide-quartz type in Northern and Eastern Kazakhstan; detecting geological and structural position of x-ore stockworks.

Methodology. Field studies within the Vasilkovske ore field in Northern Kazakhstan and the Sekisovske ore field in Eastern Kazakhstan. Sampling ore-bearing magmatic rocks and ore bodies to determine the chemical composition and distribution patterns of the main ore minerals and impurities. Microprobe analysis using a scanning electron JSM 6390LV microscope with an energy-dispersive attachment, comparative characteristics of ore mineralization in the fields studied.

Findings. Completed research and comparative analysis of data from other regions of the world show that large stockwork gold-sulphide-quartz with tellurides and bismuth-bearing ore of the Vasylkivske and Sekysivske deposits formed in a period of high tectonic activity in the earth's crust within regional geologic collision type structures, in the process of rhythmically pulsating displacement and tuck in the lithospheric plates and blocks. The position of ore stockworks is controlled by crust-magnesium deep splits, thrust structures and hypabyssal intrusions of gabbro-diorite-granodiorite-plagiogranite series. The mineralization is associated with intense tectonic crushing processes and hydrothermal-metasomatic transformation of host rocks, manifested in microclinization, albitization, propylitic alteration, beresitization and silicification as well as gaining ore minerals. The ore bodies are characterized by Au–Ag–Bi–Te specialization. The gold is of two types: free and banded with sulfides, the mineralization vertical distribution range being significant (over 500–800 m). The banded gold deposits in the Vasylkivske deposit are localized in arsenopyrites, in the Sekysivske deposit gold mineralization is banded with pyrites of several generations.

Originality. Complex compounds of silver and gold with tellurium have been revealed in the Sekysivske and, with tellurium and bismuth in ores of the Vasylkivske 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.

Practical value. The ore bodies of the studied deposits are localized in gold stockworks and breccias (with gold content from single digits to groups of ten gpt), there is a high resource potential and prospects of a significant growth of reserves. The ores are characterized by a variety of gold and silver tellurides, the high content of bismuth minerals and rare metal manifestation of specialization (Sn, Nb, Ta), which increases the profitability of the development of the deposits of this type. Tectonic, magmatic and mineralogical and geochemical factors controlling the formation of stockwork ore bodies and gold eruptive breccias, allow predicting the development of zones of mineralized breccia on the flanks and in the depth of the studied deposits. The considerable gold concentration areas, as well as the variety of related elements increase the development profitability of this type of deposits.

Keywords: *gold deposit, intrusion, stockwork, tellurides, bismuth, Kazakhstan*

Introduction. Recently the attention of researchers has been increasingly focused on large gold-sulphide-quartz stockworks and Au, Au–Ag and Au–Bi-polymetallic deposits associated with them.

The examples of such deposits abroad include giant stockworks associated with mesothermal intrusions: Fort Knox (Alaska), Jeruy (Kyrgyzstan), Cripple Creek (USA) and others.

In Kazakhstan, the deposits of this type related to various time levels from the early to late Paleozoic: Vasylkivske-Kodagyrske (O_3-S_1), Raigorodske (O_3-S_1, S_2), Yubileine (D_2), Sekysivske (C_{2-3}).

Presentation of the main research. ***The stratigraphy and magmatism of the Sekysivske deposit.*** The Sekysivske deposit area is located within the Aleysk subzone in the Rudnoaltaiska structural-formational zone. Its central and south-western parts belong to the Aleysk anticlinorium; its north-eastern part belong to the Bystrushinsky Synclinorium. 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 Sekysivske ring structure.

The geological structure of the area includes the Devonian and Carboniferous sediments: the lower strata of the Devonian Frasnian (D_3*fr*) is located in the northwestern part of the described area and is represented by lavas and tuffs of andesite-basalt composition, siliceous and argillaceous siltstone and limestone lenses of 600–700 m.

The Famennian sediments (D_3 *fm*), combined in Pihtovska suite, are developed in the southwestern part of the area. Within the suite the volcanites of intermediate and basic composition tend to the lower section (Nizhnepihtovska subsuite) accounting for 50–60 % of its capacity. Felsic volcanites are located mainly in the top section (Verhnepihtovska subsuite). Tuffsandstones, siltstones, limestones are evenly distributed and constitute 15–20 % of the section capacity. The total capacity of the Famennian sediments reaches 1900 m.

Upper-Famennian-Tournaisian sediments (D_3 *fm-tr*) are widespread and presented by andesitic and basaltic porphyries and their tuffs, lavas and tuff lavas interbedded with tuff-sandstones, siltstones and limestones. The thickness of these deposits is 500–1300 m.

The Tournasian Stage sediments (C_1*tr*) located at the described territory compose several sections and relate to the Tarkhan and Bukhtarma suite. These sediments are common in the northeastern part of the area and are presented by calcareous-clayey and clayey siltstones, sandstones. Their capacity is equal to 500–700 m (Freiman, Selifonov).

The ore field of the Sekysivske deposit is localized within the multiphase gabbrodiorit-diorite-granodiorite-granite Sekysivske massif at Zmeinogorsk collision complex (Fig. 1).

It has an area of about 100 km^2 and breaks volcanogenic-sedimentary rocks of the Famennian and the

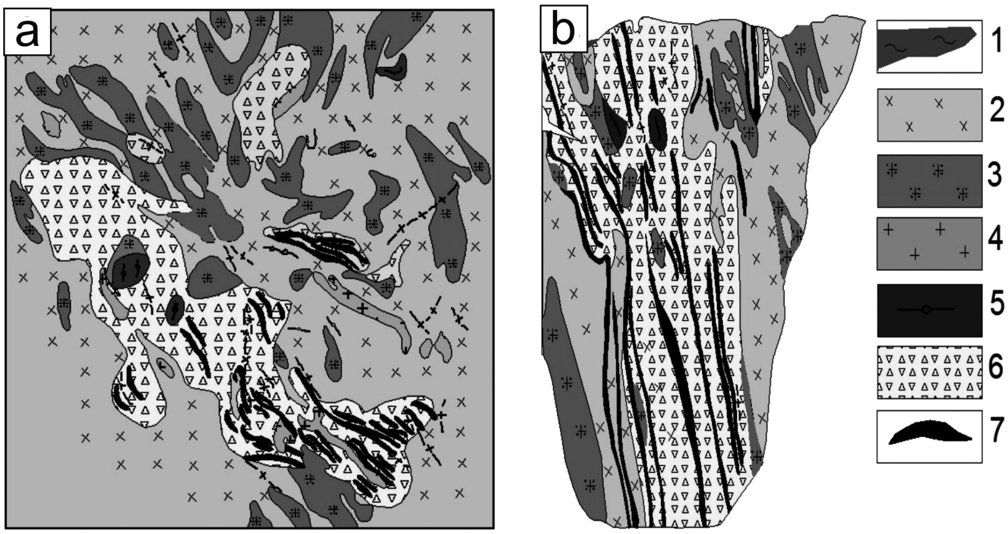

Fig. 1. Schematic geological map (a) and section of the Sekysivske deposit (b) (G. G. Freiman et al.):

1 – Quaternary sediments; 2 – granodiorites, quartz diorites; 3 – biotite-hornblende granites, plagiogranites; 4 – aplite granites, granite-porphyries and 5 – plagiogranite-porphyries at Zmeinogorsk complex (C_{2-3}); 6 – explosive breccias of mixed and acid composition; 7 – gold ore bodies

Lower Carboniferous age. Its north-eastern part is complicated by regional tectonic disturbances to the north-west, which contain localized areas of explosive-hydrothermal breccias [1].

The ore field of the deposit consists of magmatic rocks of all four phases of the Zmeinogorsk complex formation with prevailing granodiorites and diorites of the second phase and plagiogranites of the third phase of the complex implementation (more than 90 %). The rocks of the first phase are only found in the south-eastern and north-western parts of the ore field; they constitute outliers among magmatites of later phases.

The gabbroid bodies have a complicated form, which is a little elongated in the north-west direction. Their size varies from 300–500 to 2000 m. The rocks of the second phase of implementation constitute 35–40 % of the central part of the ore field; they are limitedly spread on the flanks.

The bodies of diorites and granodiorites are typically elongated in the north-west and meridional direction; they are found as xenoliths of different sizes in the rocks of the third and fourth phases of implementation [2].

The rocks of the third phase with prevailing plagiogranites make up the bulk (over 60 %) of the ore field, they are mostly distributed in the flanks (Fig. 2). They form very large bodies (hundreds of meters, and the first kilometers) of complex shape, with numerous embedding xenoliths of magmatites of earlier implementation phases. The rocks of the fourth phase are developed at the intersection sites of different disjunctive dislocation in the south-east and north-west flanks of the ore field; they compose bodies of sizes from 0.5 × 1.0 to 1.0 × 2.0 km [3].

Northwest faults in conjunction with flexure bends and breaks in other directions control the location of explosive-hydrothermal breccia, ore bodies and dykes.

The two largest of them pass through the Sekisovskoe deposit and Tserkovsky ore occurrence and are the fragments of Shemonaikha-Narym lineament.

Submeridional and northeast dislocations with subvertical and steep dips are more recent, they are responsible for the deposit block structure, affect the morphology of the bodies of dike series and lead to shear movement. Sublatitudinal cracks occur limitedly, they are fixed with staggered relief benches, and fractures in granitoids [4].

Mineralization. Ore-bearing rocks at the deposit are breccias of tubular, elongated shape with the sizes from 40 × 100 meters to 120 × 500 m. Their traced depth exceeds 950 m. There are two points of view on the genesis of the breccias. According to one point of view, they are magmatic rocks (Kuznetsov et al.), according to the other, which is shared by most researchers, they are explosive-hydrothermal rocks (Selifonov S. E. et al.; Freyman G. G.).

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).

There are 4 types of breccias: explosive-hydrothermal breccias of average composition; explosive-hydrothermal breccias of medium – basic composition; explosive-hydrothermal breccias of mixed composition; explosive-hydrothermal breccias of acid composition.

The difference in fine- and coarse breccia bodies have been established. The intense degree of hydrothermal alterations is more common for the first ones. The size of fragments ranges from 0.1 to 2 m with prevailing fragments of 0.1–0.5 m and large blocks of host rocks occur sometimes.

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 1 to 15 %, on average 5 %. Gold mineralization is spatially and genetically associated with sulfides, but a direct correlation between the sulphide and gold content was not established [5].

The gold is unevenly distributed and forms a kind of nest-ripple type of mineralization. Higher concentration gold ripple 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: a central zone, which consists of two sub-zones – a north-eastern subzone (group of ore bodies 3, 5, 6 and 8) and a southwestern subzone (group of ore body 1); a northern zone (group of ore body 2); a north-western zone (group of ore bodies 12, 13); a western zone (group of ore body 11); a southwestern zone (group of ore body 10).

The main ore bodies are not contoured by down dip, the bodies have a band-like and a phacoidal shape with the predominance of length of the dip over the width of the strike. The average thickness (competence) of ore bodies varies from 0.58 to 3.28 m. The orientation of ore bodies along the strike coincides with the orientation of the ore zones (breccias).

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

At a later stage of a mixed-type breccia formation a gold-silver-bismuth-tellur-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. Quartz carbonate and quartz sulfide veins predominate. Gold is found as free metal, tellurides (Fig. 3), finely-dispersed impurities in sulfide [6].

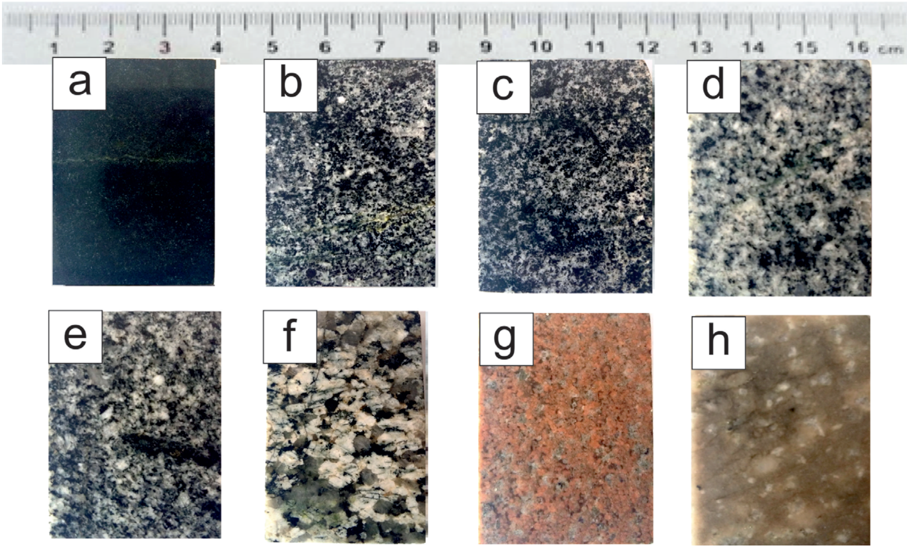

Fig. 2. The main intrusive rocks of the Sekysivske deposit:

a – gabbro; b – gabbrodiorite; c – diorite; d – quartz diorite; e – granodiorite; f – plagiogranite; g – granite; h – granite-porphyry dykes

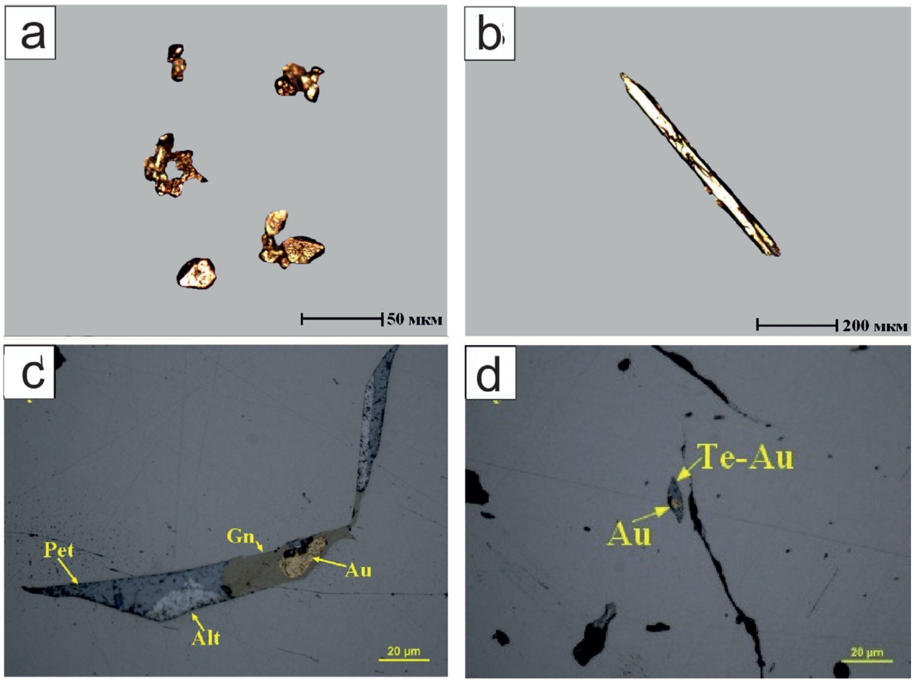

Fig. 3. Some forms of gold and tellurides in ores of the Sekysivske deposit:

a, b – gold native, microscope Olympus BX-51; c, d – tellurides of gold; Au – gold native; Pet – petzite, Alt – altaite; Gn – galena; Te–Au – tellurides of gold, scanning electron JSM 6390LV microscope

The Vasylkivske deposit stratigraphy and magmatism. The deposit is located in Northern Kazakhstan at the Kokshetau Terrain – a large block of Precambrian metamorphic rocks, exposed to intensive granitisation and accretion in the Phanerozoic.

The main structural elements of the Vasylkivske gold district are the northeastern margin of the Kokshetau Terrain; the intersection of the regional NW-trending Dongulagash and Akekseevka faults; the NE-trending Vasylkivske-Berezovka Fault and the Latitudinal Fault; and the North Kokshetau ellipsoid domal-ring structure 55 × 30 km within an area affected by domes of the second order [6].

The most of the Vasylkivske district is occupied by the Ordovician North Kokshetau domal pluton of the Zerenda Complex (gabbro, gabbrodiorite, diorite, granodiorite, plagiogranite, and monzonite) elongated in the northwestern direction. The Complexity of intrusive phases, transitions of textural variations and alteration facies, frequent alternation of rock types with banding, schlieren and branching offsets, hybridisation zones, resorbed migmatites and enclaves are typical further complicated by shearing and thrusting (Fig. 4).

The early intrusive phases composed of gabbro and gabbrodiorite are characterized by elevated alkalinity with prevalence of sodium over potassium. The late felsic intrusive phases are depleted in CaO, MgO, total FeO, and Al_2O_3 along with enrichment in SiO_2, high $Na_2O + K_2O$ (10–12 wt %) and predominance of K over Na (4 : 1).

Typical intrusive rocks of gabbroid and granitoid series at the Vasylkivske deposits are shown in Fig. 5. Granodiorite is affected by K-feldspathization. Red to pinkish-grey and grey microcline porphyroblasts occupy 5–10 and 45–70 % of the rock volume, respectively. Fine-grained granite, aplite-like granite, and pegmatite dykes are abundant. Pegmatites also occur as sills and schlieren [7].

Red sediments D_{2-3} and terrigenous-carbonate deposits of age C1 are located at the south-western flank of the area. The north-eastern flank consists of the Upper Riphean-Vendian carbonaceous terrigenous-carbonate Sharyk Formation (Sharykskaya suite) with increased gold content. Subordinating amphibolites, schists and gneisses of the lower-middle Proterozoic and flishoids of middle-upper Ordovician.

The Main Mineral Parageneses of the Vasylkivske deposit. The Vasylkivske gold field is localized at the intersection of Dongulagash and Vasylkivske-Berezovka Faults; it has a frame-block tectonic structure and contrasting hydrothermally altered rocks.

The Vasylkivske deposit is associated with the contact of gabbro-diorite and diorite with hornblende-biotite granodiorite 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. 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 Vasylkivske 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 (Fig. 6).

A syn-mineral microcline is framed by gold-bearing quartz-arsenopyrite veins and arsenopyrite veinlets in the form of hems and ribbons up to 1–5 cm. It is most likely that the most recent derived kalifeldspath forms thin (0.1–0.5 cm) winding, threadlike punch-

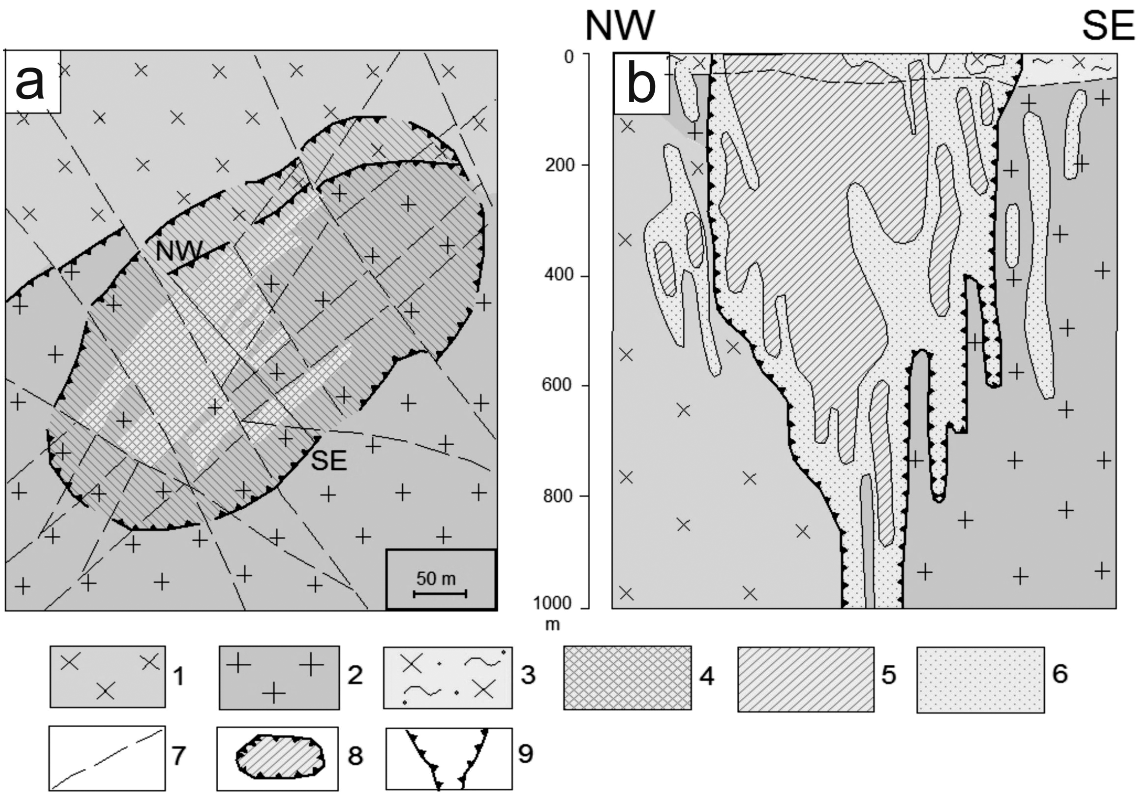

Fig. 4. The geological-structural position (a) and the geological section of the Vasylkivske gold district (b) (after Rafailovich, 2009). Geological complexes:

1–2 – Intrusive rocks of O_3-S_1 (Zerendinsky complex): 1 – Undivided gabbro-diorites, diorites; 2 – Granodiorites, Plagiogranites; 3 – Clayey – rock debris weathering crust; 4 – Gold-bearing stockworks; 5–6 – Grades of gold in gold-bearing stockwork: 5 – Medium and high, 6 – Low; 7 – Faults; 8 – Boundary of vein and vein-disseminated gold mineralization; 9 – Boundary of gold-bearing stockwork in section

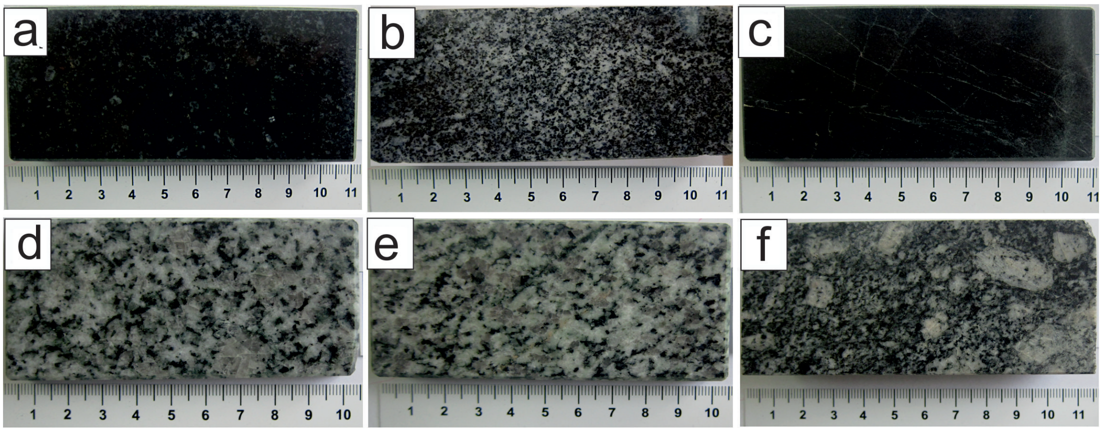

Fig. 5. Igneous textures of typical rock suites at the Vasylkivske deposit:

a – gabbro; b – gabbrodiorite; c – diorite; d – quartz diorite; e – plagiogranite; f – granodiorite

ing, intersecting quartz-arsenopyrite veins, lenses and bonnies. Interspersed gold-bismuth-pyrite-arsenopyrite-quartz mineralization is associated with kalifeldspaths.

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 combination. Chlorite-albite metasomatic rocks are developed upslope of the ore-bearing structures for hundreds of meters.

Gangue minerals (quartz, carbonate, tourmaline, sericite, and fluorite) are widespread; they form typical relationship with ore-metasomatic bodies, thin quartz-

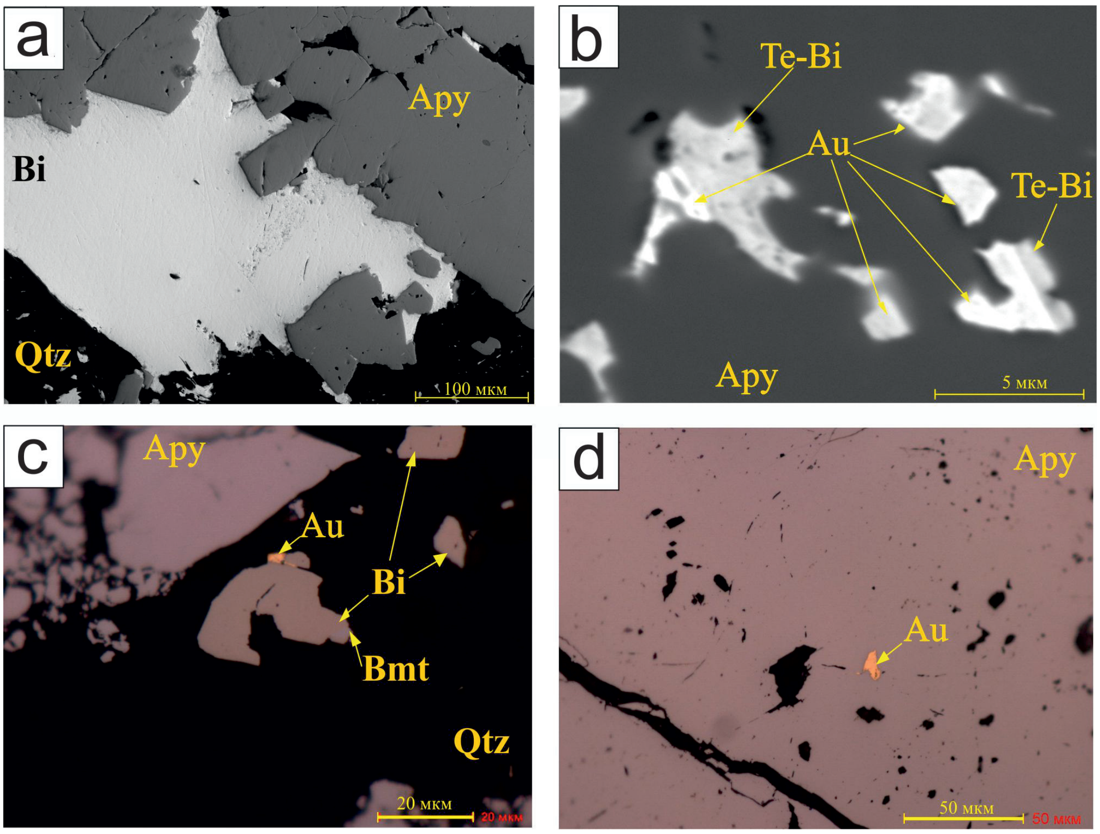

Fig. 6. Gold in the ores at the Vasylkivske deposit:

a – visible gold (Au) in arsenopyrite (Apy); b – gold with the admixture of bismuth in association with tellurovismutite (Te-Bi) – scanning electron JSM 6390LV microscope; c – Gold (Au) with the admixture of bismuth (Bi) and vismutite (Bmt) (microscope Olympus BX-51); d – visible gold (Au) in arsenopyrite (Apy) (microscope Olympus BX-51)

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tourmaline and quartz-pyrite veins preceded kalifeldsparization, beresitization and gold mineralization: the first (quartz-tourmaline) veins developed in the stem zone; the second (quartz-pyrite) veins form a halo, far beyond the limits of the ore stockwork.

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 extend in the stockwork frontal zone. Postmineral formations 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.

There are early and recent mineral associations. The early association is pyrite-pyrrhotite-marcasite-quartz; actual ores are gold-pyrite-arsenopyrite-quartz (with pyrrhotite, loellingite, chalcopyrite), gold-bismuth-pyrite-arsenopyrite-quartz (molybdenite, scheelite, cubanite, native bismuth, bismuthine, tetradymite heterochronous fahlore ore); and gold-polymetallic association (with chalcopyrite, sphalerite, galena, tennantite).

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. The pyrite forms punching, aggregative clusters and cuboctahedral crystals containing thin grains of native gold and bismuthine. Arsenopyrite makes veins, rosette and pectinal formations, lentil and nodular splashes, irregular impregnation in quartz and hydrothermally altered rocks [8].

The forms of arsenopyrite are porphyroblastic and hypidiomorphic effusions, lathlike, and pseudo-bitapered crystals the size of a thousandth of 1 mm to 2 or 4 mm. Arsenopyrites contain Au (up to hundreds of mg/t), Ag (5–50 g/t), Bi (up to 100–300 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/t).

The arsenopyrites in the upper horizons are enriched in Sb, Ag, Cu; the arsenopyrites in medium and deep horizons – in Zn, Mo, Bi, Co, Ni. The highest concentrations of Au and associated elements are typical for fine-grained variations of arsenopyrites.

The bulk of the gold is associated with pyrite-arsenopyrite-quartz and bismuthine-pyrite-arsenopyrite-quartz associations. Two generations are predominant: a generation embedded in arsenopyrite and a free one in quartz. The gold is the size of tenths of a micron to 0.12 mm, it forms rounded, teardrop-shaped, amoeboid, cloddy and irregular (erratic) effusions, rhombic-dodecahedron shape crystals and their aggregates. The purity of gold is 840–950.

Mineral zoning is manifested at the level of paragenetic associations and particular minerals. Pyrite-pyrrhotite-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 (Chekvaidze V. B.).

The main indicator elements of the deposit are Au, As, Bi (the contrast is hundreds or thousands of abundance ratio), less contrasting ones are W, Sb, Ag, Cu, Pb, Hg (units or a few) tens of abundance ratio), weak contrasting ones are Zn, Mo, Ni, Co , Cr, Mn (units of abundance ratio).

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. 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.

Bismuth is closely associated with pyrite-arsenopyrite mineralization. In disseminated and vein-disseminated ores with the content of Bi equals 5–10 g/t, in veinlet ores it is 10–50 g/t in ore columns it is up to 100–1500 g/t. Gold has a close correlation with the elements of the ore stage – Bi, As, Ag, Pb, Cu.

Conclusions. The Sekysivske and Vasylkivske deposits are stockwork-type gold deposits which are characterized by a long range (hundreds of mln. years) of ore-preparation and ore-forming processes, the situation of mesothermal depths during periods of high tectonic activity in the Earth's crust. They tend to be regional suture zones of major lithospheric blocks and are locally confined to domes, ring structures, thrusts, and shear zones.

They are characterized by multiphase granitoid intrusions of increased and high IS-type alkalinity, the metamorphism of enclosing rocks, the same hydrothermal alterations (kalifeldsparization, beresitization, propylitization), explosive breccias, Au–Ag–Bi-Te specialization, several generations of native gold, a zonal structure of stockworks [9].

A more profound study of the source of gold using a simulation of physical and chemical processes of mobilization, transport and deposition of ore matter allows recommending new mineralogical and geochemical techniques, methods of prospecting and evaluation of deposits of this type.

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Мета. Виявлення закономірностей розподілу золоторудної мінералізації та супутніх елементів у золотоносних штокверках великих родовищ золото-сульфідно-кварцового типу Північного й Східного Казахстану, визначення геолого-структурної позиції в рудних штокверках.

Методика. Польові дослідження в межах Васильківського рудного поля в Північному Казахстані та Секісовского рудного поля у Східному Казахстані. Відбір проб із руд, що містять магматити та рудних тіл для визначення хімічного складу й виявлення закономірностей розподілу основних рудних мінералів і домішок. Мікрозондовий аналіз за допомогою скануючого електронного мікроскопа JSM 6390LV з енергодисперсійною приставкою, порівняльна характеристика рудної мінералізації досліджуваних родовищ.

Результати. Великі штокверкові золото-сульфідно-кварцові з телуриду й вісмутмісткими рудами родовища Васильківське та Секісовське сформувалися в період високої тектонічної активності земної кори в межах регіональних геологічних структур колізійного типу у процесі ритмічно-пульсаційного зрушення й підкоміра літосферних плит і блоків. Положення рудних штокверків контролюються системами коро-магнійних глибинних розломів, надвіговими структурами та гіпабіссальними інтрузіями габро-діорит-гранодиорит-плагіогранітової серії. Рудоутворення пов'язане з інтенсивними процесами тектонічного дроблення й гідротермально-метасоматичного перетворення порід, що вміщають, які проявляються в мікроклінізації, альбітізації, пропілізації, березитизації та окварцюванні, а також привнесенні рудних мінералів. Рудні тіла характеризуються Au–Ag–Bi–Te-спеціалізацією. Золото двох типів: вільне й пов'язане із сульфідами, вертикальний діапазон розподілу зруденіння значний (більш 500–800 м). Пов'язане золото родовища Васильківське локалізується в арсенопіритах, на Секісовському родовищі золоторудна мінералізація пов'язана з піритами декількох генерацій.

Наукова новизна. Виявлено значне поширення складних з'єднань золота й срібла з телуром (Секісовське родовище), а з телуром і вісмутом (Васильківське родовище).

Комплексність руд передбачає постановку задачі різнобічного обліку основних і супутніх компонентів при проведенні всіх стадій робіт: починаючи з геолого-оціночних до експлуатаційної розвідки. Сучасні технології збагачення, новітні способи розробки дозволяють зараз віднести ці родовища до об'єктів першочергового промислового освоєння. Їх вивчення має наукове значення в питаннях ендогенного рудоутворення та створює передумови виявлення нових перспективних площ і родовищ як у Казахстані, так і в інших регіонах світу.

Практична значимість. Рудні тіла досліджуваних родовищ локалізуються в золотоносних штокверках і брекчіях (із вмістом золота від перших одиниць до десятків г/т), відзначається високий сировинний потенціал і перспективи значного приросту запасів. Руди характеризуються різноманітністю теллурідов золота, срібла. Високий вміст у них мінералів вісмуту та прояви рідкометальиої спеціалізації (Sn, Nb, Ta) підвищує рентабельність освоєння родовищ даного типу. Тектонічні, магматичні й мінералого-геохімічні чинники контролю утворення штокверкових рудних тіл і золотоносних вулканічних брекчій дозволяють прогнозувати розвиток зон мінералізованих брекчій на флангах і глибину досліджуваних родовищ. Значний розмах концентрації золота, а також різноманітність супутніх елементів підвищують рентабельність освоєння родовищ даного типу.

Ключові слова: *родовище золота, інтрузія, штокверк, теллуріди, вісмут, Казахстан*

Цель. 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.

Методика. Полевые исследования в пределах Васильковского рудного поля в Северном Казахстане и Секисовского рудного поля в Восточном Казахстане. Отбор проб из рудовмещающих магматитов и рудных тел для определения химического состава и выявления закономерностей распределения основных рудных минералов и примесей. Микрозондовый анализ с помощью сканирующего электронно-

го микроскопа JSM 6390LV с энергодисперсионной приставкой, сравнительная характеристика рудной минерализации изучаемых месторождений.

Результаты. Крупные штокверковые золото-сульфидно-кварцевые с теллуридами и висмутсодержащими рудами месторождений Васильковское и Секисовское сформировались в период высокой тектонической активности земной коры в пределах региональных геологических структур коллизионного типа в процессе ритмично-пульсационного сдвижения и подворота литосферных плит и блоков. Положение рудных штокверков контролируется системами корово-магнийных глубинных разломов, надвиговыми структурами и гипабиссальными интрузиями габбро-диорит-гранодиорит-плагиогранитовой серии. Рудообразование связано с интенсивными процессами тектонического дробления и гидротермально-метасоматического преобразования вмещающих пород, проявляющимися в микроклинизации, альбитизации, пропилизации, березитизации и окварцевании, а также привносе рудных минералов. Рудные тела характеризуются Au–Ag–Bi–Te-специализацией. Золото двух типов: свободное и связанное с сульфидами, вертикальный диапазон распределения оруденения значительный (более 500–800 м). Связанное золото месторождения Васильковское локализуется в арсенопиритах, на Секисовском месторождении золоторудная минерализация связана с пиритами нескольких генераций.

Научная новизна. 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.

Практическая значимость. Рудные тела изучаемых месторождений локализуются в золотоносных штокверках и брекчиях (с содержаниями золота от первых единиц до десятков г/т), отмечается высокий сырьевой потенциал и перспективы значительного прироста запасов. Руды характеризуются разнообразием теллуридов золота, серебра. Высокое содержание в них минералов висмута и проявление редкометалльной специализации (Sn, Nb, Ta) повышает рентабельность освоения месторождений данного типа. Тектонические, магматические и минералого-геохимические факторы контроля образования штокверковых рудных тел и золотоносных вулканических брекчий позволяют прогнозировать развитие зон минерализованных брекчий на флангах и глубину изучаемых месторождений. Значительный размах концентрации золота, а также разнообразие сопутствующих элементов повышает рентабельность освоения месторождений данного типа.

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

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