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METALLOGENY OF POLYMETALLIC MINING OF TYAN-SHAN

Razikov O. T.
SU "Institute of Mineral Resources (IMR)", State Committee for Geology of the Republic of Uzbekistan. Tashkent, Uzbekistan
odil.razikov@mail.ru

Akbarov Kh. A.
Tashkent State Technical University, University, Tashkent, Uzbekistan
khakbarovCd) @ rambler.ru

ABSTRACT
The paper describes the results of long-term studies of the geological-structural types of polymetallic ore fields and deposits of the Tien Shan. Twenty-two types of ore fields and deposits have been identified, which are combined into five geological and structural groups:1) folded ore fields and deposits; 2) fractured ore fields and deposits; 3) ore fields and deposits of volcanic structure; 4) contact ore fields with deposits with a predominant influence on the position of mineralization; 5) mineralization of contact structures of heterogeneous composition and genesis (contacts) of rocks.

KEYWORDS: ore field, deposit, folded, fractured, contact, structural-morphological, ore body.

INTRODUCTION

In the long-term period of studying polymetallic ore fields and deposits of the Tien Shan, researchers have accumulated a huge amount of factual materials on the geological and structural conditions of the formation and placement of polymetallic mineralization. The objects of study are several tens of fields and deposits of polymetallic ores of various sizes in the Tien Shan (Fig. 1).

Collection and generalization, analysis of cartographic materials, diagrams, geological plans and sections of individual ore fields, statistical analysis of various deposits, as well as metallogenic assessment of mineralization and development of computer processing methods using modern GIS technologies and programs using the ArcGIS method of geological data for the purpose of local forecasting [7, 9].

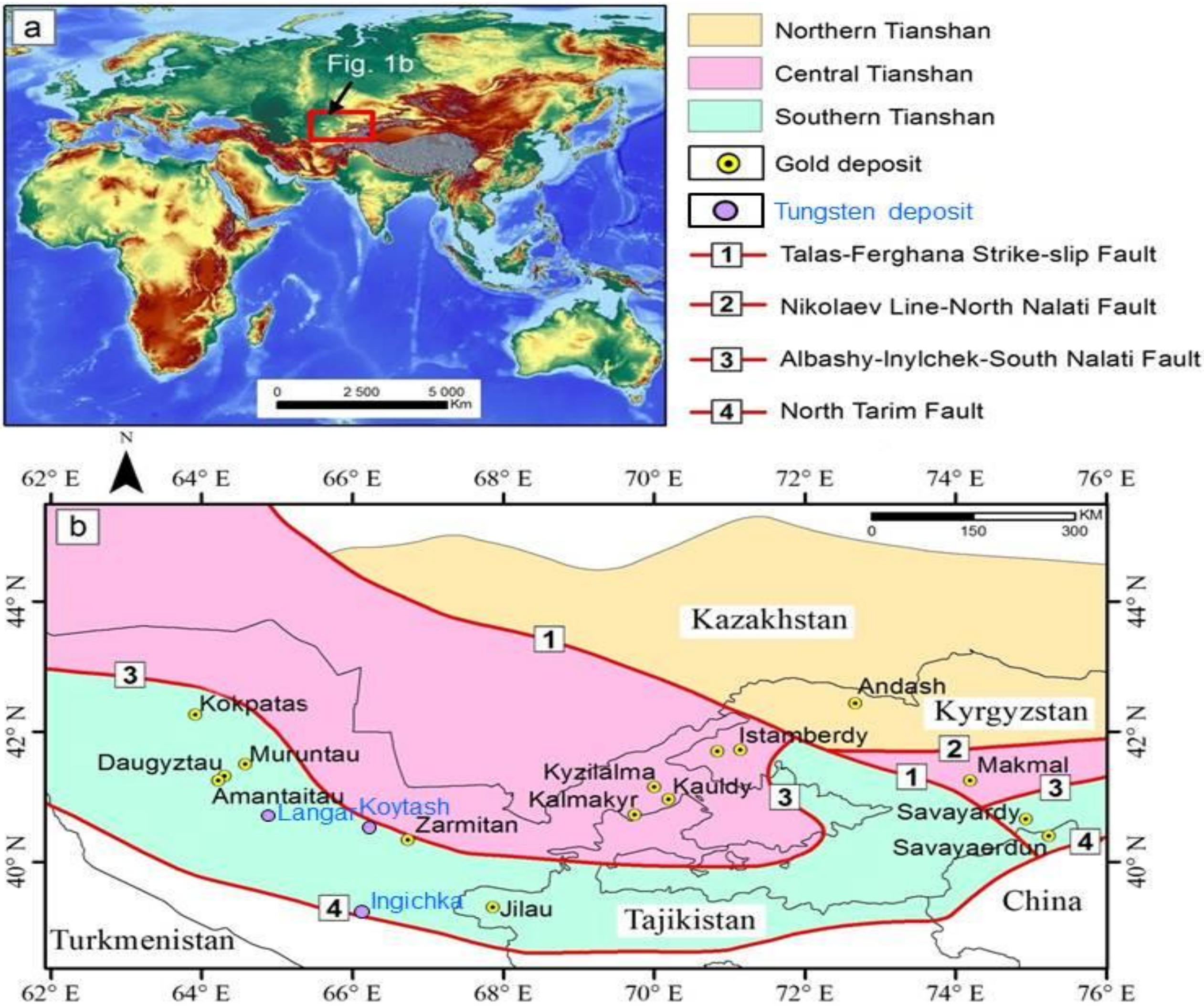

Fig. 1. (a) Map of digital elevation model of the world (b) Geological map of part of the territory of the South Tien Shan orogen in Central Asia (modified after Lei et al., [5].; Goipov et al., [3]).

The proposed systematics of the structural types of ore fields and deposits is based on the feature of a set of structural elements that determine the nature of deformation of the enclosing strata and related features of the location of mineralization. It includes the main factors in the location of mineralization and establishes a definite relationship between the scale of ore fields, lithological composition, host strata, and structural complexity. This allows you to direct the study to identify, first of all, large objects. Five main groups of ore fields and deposits with a predominant influence on the location of mineralization: 1) folded forms (folded); 2) ruptured structures (ruptured); 3) volcano-tectonic structures); 4) structures of contacts of dissimilar rocks (combined); 5) folded, fractured and contact structures of dissimilar rocks (combined) [4, 10, 12, 13].

Folded ore fields and deposits with a predominant influence on mineralization placement of folded structures (folded)

They are mainly associated with folded structures in relatively plastic carbonate, carbonate-terrigenous and volcanogenic formations. Within the group, there are five geological and structural types of ore fields and deposits: 1) in single monoclines; 1) in single anticlines; 3) in bends, undulations and periclinal closure of anticlines; 4) in anticlines complicated by cracks; 5) in synclines complicated by cracks.

Deformations associated with folding, mainly with bends, waves of folded structures, consisting of relatively uniform plastic thicknesses; affect the placement of mineralization in folded ore fields. Fracture tectonics is important at the end of fold formation, while fractures obey folds in placement. This group of ore fields and deposits is distinguished by the predominance of concordat ore bodies (Fig. 2). Among the concordate ore bodies, saddle and domed deposits are noted in the splitting of anticlinal arcs (1, 2), deflections in the axial and adjacent parts of the depressions (3, 4), saddle and winds domed in cross-section (5), lenses and lenticular deposits in complications associated with a change in the angle of incidence (6, 7), dome-shaped wavy bodies in combination with complications of fall and extension (8), lamellar into through contacts (9, 10) , lamellar contact deposits in the wings, and sagging of synclines (11, 12, 13). Selective replacement bodies are formed in permeable, weakly dislocated formations, the rocks of which have high porosity and chemical activity (intro- and interformational bodies. They form stratal deposits, lenses and ribbons in monoclines, wings and axial parts The length of concordat ore bodies ranges from 20 to more than 1000 m , width from 10 to more than 800 m, thickness from 2 to 30 m.

A characteristic feature of folded ore fields and deposits is the large-scale predominance of sheet-like concordat ore bodies [1, 2, 11].

1. Ore fields and deposits in single monoclines (Tytlu-I, Dauletsay, Mukhamed). Monoclinic folding is mainly manifested in platform conditions. Folds appear in carbonate strata of bedding of monoclines and volcanogenic formations - in the wings of gently sloping anticlinal structures with local folds of a lower order.

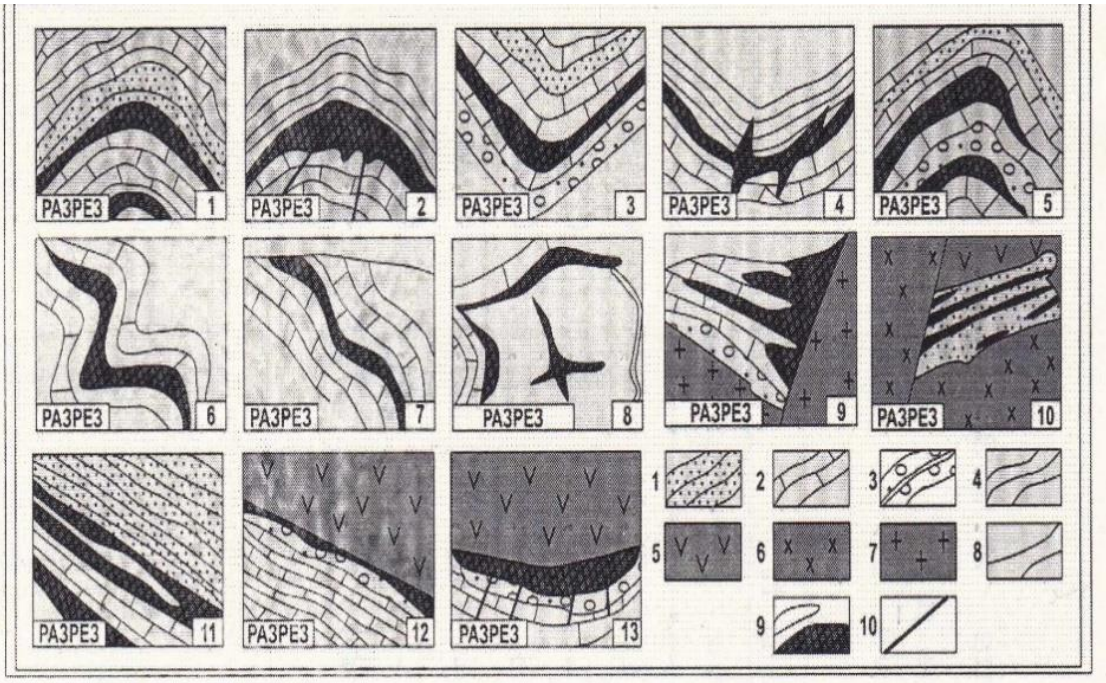

Fig. 2. Structural and morphological types of concordat ore bodies.
1 - sandstone; 2 - limestone and dolomite; 3- basal tuff conglomerates; 4 - slate; 5 - quartz porphyrite; 6 - welded tuff of dacite porphyry; 7 - granodiorites; 8 - significantly altered shale; 9 - ore bodies; 10 - malfunctions.

2. Ore fields and deposits in separate anticlines (Jergalan, Ikichat, Kassan). Like the previous type, single anticlinal structures in the mobile regions of the geosynclinal are rare, since folded systems are usually formed here. These structures are formed in carbonate strata in the presence of subparallel or converging faults, which create conditions for blocking the fold wings.

3. Ore fields and deposits in bends, waves and periclinal closure of anticlines (Mirgalimsay, Ainalma, Fig. 3) emerge in the rocks of carbonate and carbonate-terrigenous formations; they are preferably placed in the wings of large anticlinal structures along deep linear faults. In places of folds bends, transverse and transverse faults develop, which are combined with linear ones. In general, the scale of ore fields is small. The exception is the Mirgalimsay ore field.

4. Ore fields and deposits in anticlines complicated by faults (Kuldara, Sumsar, Baijansai, Kugitang, Kanjailai, Brichmulla, Sarykan, Levoberezbnoe, Tazacharvinsky, Araltau, Bazartybe, Gerkhan, Kurganasht) are formed in carbonaceous carbonate and re-volcanic rocks formations in the wings of large anticlinal systems and less often in their axial parts.

They are controlled by transverse and their violations associated with folds of smaller orders. The faults form complex zones and are accompanied by dike belts. The main factors controlling mineralization are splitting, selective crushing of

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larger strata, a combination of through disturbances with lithologically favorable rocks. Are essential pre-ore transformations of deposits (especially silicification), which increase their fragility, permeability and, in some cases, chemical activity. For example, in the Sumsar ore field, two horizons of dolomites, lying between layered clayey limestones, underwent fragmentation.

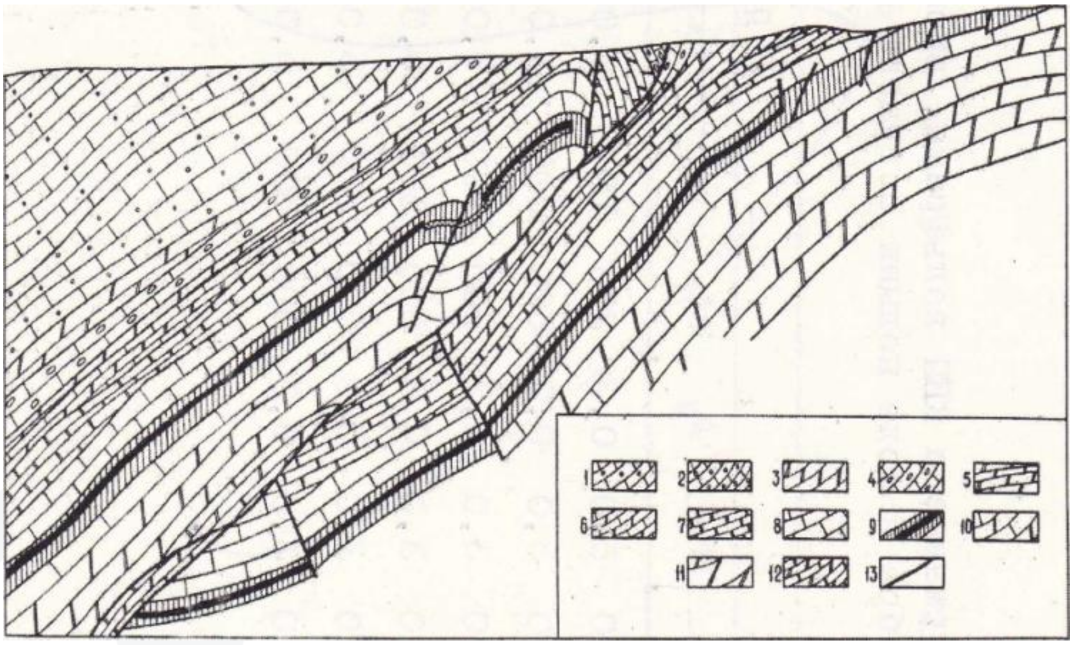

Fig. 3. Geological section of the Mirgalimsay deposit.

1 - limestone and limestone breccia; 2 - limestone with dolomite; 3 - massive, rarely layered dolomites; 4 - basal limestone breccia with dolomite massifs; 5 - belt dolomites; limestone; 6 - flag-shaped, dolomitized; 7 - lumpy, layered; 8 - large-leaved; 9 - the same, dolomites with ore; dolomites: 10 - large-leaved; 11- dolomites; 12 - shredded tape; 13 - malfunctions

5. Ore fields and deposits in synclines complicated by faults (Khandiza, Perevalnoe, Chamova, Chinarsai, Novasai, Vakhsivar, Malyangur) occur in thick carbonate-terrigenous strata. They are known from the structural belts of the Middle and Upper Paleozoic. They are located in the wings of large synclinal structures complicated by faults. In some cases, the faults were channels of volcanic flows. The ore bodies are predominantly concordate, transforming into complex ore bodies near the faults. In the latter, the intensity of mineralization increases.

Fracture in ore fields and deposits with a predominant influence on the location of mineralization of destroyed structures (fracture)

They are mainly associated with disjunctive disturbances in brittle volcanic and intrusive rocks - fractured and less often isolated zonal in the form of simple and complex faults, transversely oriented to the main flow.

Relative movements play a significant role in the placement of mineralization along fault structures; they are often associated with bends in the underlying folded structures. Folded deformations develop to a greater extent due to the impact of faults. Ore-bearing and control faults are usually split, less often isolated ones are represented by simple and complex faults and tectonic zones.

Mineralization is localized in the bending regions of the fault surfaces. Through structural-geological types of ore bodies are widely developed in ore fields and deposits of the disturbed group (Fig. 4). The group of intersecting ore bodies includes a pit and veins in bent single faults (1); lens and veins in traces of detachment (2); lens in tectonic packs (3); saw down the veins in the cleavage cracks (4); dike-like bodies at the joints of support cracks, cleavage cracks with the main paths (5); complex and steep deposits in feathered faults (6); gentle and steep keeled deposits and pits in the caps of the main fault and fissures (7); wedge-shaped bodies in fault couplings (8); poles, lenses, ribbons and rods of irregular shape that have arisen when veins are overlapped by formation disturbances (9) and cracks by dikes (11); veins, ribbons, nests and bodies of irregular shape at the intersections of steep and gentle cracks (14); lenses, ribbons and poles in systems of subparallel tectonic surfaces (15); ladder veins between parallel faults (16); complex veins that arose during repeated crushing along early mineral veins (17); bodies of irregular shape in places of crushing between faults (18); stockworks in the zone of confluence of faults (19); a scar on the body (20). Ore bodies are widely represented in all groups of ore fields. Their sizes vary from medium to large: length from 10 to more than 1000 m; width. 5-900 m; thickness - from 1 to more than 30 m.

Among the ruptured ore fields and deposits, seven geological-structural types of positions of ore fields and deposits are distinguished:

6) distortions of surfaces in case of separate violations of discontinuities; 7) in distortion parts of subparallel faults; 8) cohesion and intersection of more than two faults; 9) complex malfunctions; 10) zones of crushing and shale formation; 11) tectonic areas and blocks of homogeneous faults; 12) wedge-shaped tectonic formations [2, 4].

6. Ore fields and deposits in surface bends in some breakthrough faults (Kentor, Harkush, Darbaza, Kyzylsay, Berkut, Aksagata, Koshmagat, Granitogorsk, Kokomeren, Cholokterek, Takob, Gudas are located mainly in rocks of intrusive formation in the wings of large anticlines. Often they are confined to disjunctive faults in the plumage of large deep-seated faults Mineralization is localized in curved sections of the fault, which were removed and opened.

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Depending on the type of strike slip along faults, ore bodies were represented by different morphological types: ore poles occur during shears, which are controlled by changes in the elongation of the fault, and lenses - during discharges and thrusts. Usually these are veins of simple structure, the sizes of which vary in a wide range. An important factor that predetermines the localization of mineralization is a combination of rocks showing increased mechanical strength and higher resistance to mechanical stress, conservation of open fracture cavities.

7. In the rocks of volcanic and intrusive formations, ore fields and deposits are known in the areas of bends of subparallel faults (Kenshanyk, Korolevo, Elchi, Uchochflk, Akkul, Chukur-Dzhilga, Agrankul). Tectonic elements that control the localization of mineralization and the boundaries of ore fields are also the surfaces of intrusive contacts. Ore fields are usually formed at the places of bends in faults or other tectonic surfaces. The content of ore is very different - bismuth, ore gold, meycurium, fluorite, ore tin ore mineralization.

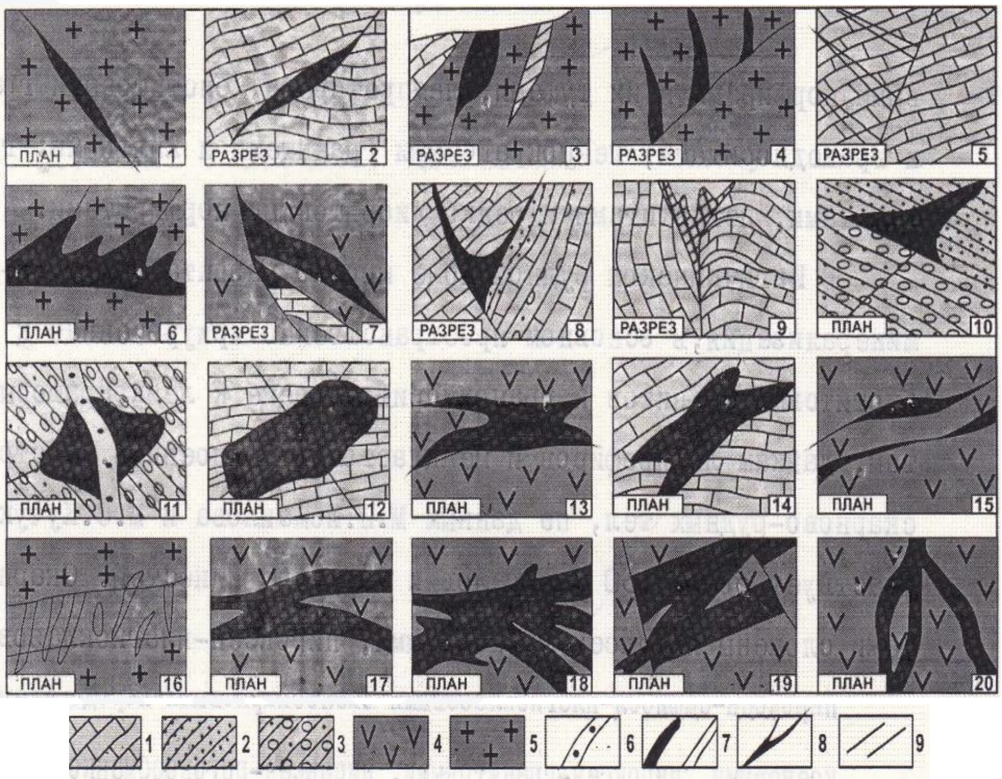

Fig. 4. Structural and morphological types of cut-in ore bodies.

1 - limestone and dolomite; 2 - sandstone; 3 - basal conglomerates; 4 - quartz porphyry tuffs; 5 - granodiorites and granite; 6 - dikes of diabase porphyrites; 7 - ore bodies; 8 - faults; 9 - direction of movement along the faults.

8. Ore fields and deposits at the junctions and intersections of more than two faults (Arsy, Kanigut, Northern Kantau, Kulkermes, Maidanshah, Tanaverdy, Sharkratma, Sardob, Kuvaki, Kenkol) are limited and occur in rocks of the intrusive formation; they are confined to the intersections or junctions of faults that bound large tectonic blocks. Despite the confinement to the intersections of faults, mineralization during movements occurring during the period of mineral formation accumulated in the feathered cleavage fissures, along which displacements occurred.

In this case, the bends of one of the defects of the coupling become more open. Ore bodies are in the form of a steeply dipping pole, forming lenses that break out along the current, extension.

9. Ore fields and deposits in complex faults (Achisai, Karasai, Karatoshkotan, Shamyrsai) are the most widespread, evenly distributed in carbonate, effusive, intrusive formations and less often in shale formations. Structurally, they develop in the wings of folded structures, in the areas of synclinal deflections and subsidence forms. Most often they are found in large tectonic blocks, limited by extended deep faults, in the form of obliquely oriented through disjunctive faults, demonstrating multiple branching and plumage of small cracks and faults. Mineralization forms systems of sub-parallel, echeloned steeply dipping orebodies and zones that are often deflated by fall and extension; however, in general, the vertical range of mineralization can reach many thousands of meters. The scale of ore fields and deposits in complex faults is different; however, medium and small ones predominate.

10. Ore fields and deposits in zones of shale formation and crushing (Taldybulak) are manifested in strata of layered rocks in regional tectonic zones and less often in intrusive ones. Positions favorable for the localization of lenticular, strip and saddle bodies are formed in the zones of bends and layered structures that arise when small folds are formed in conditions of their blocking by transverse and linear faults with repeated displacements.

11. Ore fields and deposits in tectonic plates and blocks (Chonot, Tashgese) of homogeneous faults are formed in longitudinal faults at the stages of tectonic extension in the wings of synclinal structures complicated by crossed uplands. They are known in carbonate and intrusive formations.

12. Ore fields and deposits in wedge-shaped structures (Kulchulak, Karakhana, Aktashkoro, Kanimansyr-Kara-Kaslikotan, Kulpaksay, Kandzhol, Myshykkol, Kichiksay, Zambarak, Tarjekan are noted in all rock formations; they are developed in volcanogenic formation.

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Large tectonic blocks appear along large faults and small faults in plumage; they are broken down into smaller wedge-shaped bodies through cracks in which mineralization is localized.

Opposite displacement patterns arise when wedge-shaped blocks are pressed along the limiting faults. The nature of the localization of mineralization in wedge-shaped structures depends on the morphology and kinematics of faults and the physicochemical properties of rocks.

Basically, these two factors predetermine the distribution of tectonic stresses in wedge-shaped blocks and the corresponding deformations of rocks, arising under the action of horizontal compression, normal for their long axis. In the absence of morphological complications in the limiting faults, the stresses are controlled along the faults and grow symmetrically towards the base of the block, which indicates an emerging tendency for its compression. The increasing complexity of the morphology of limiting faults significantly changes the picture of stress distribution.

If there is a section in the confining fault that, due to its orientation, under the conditions of compression of the wedge-shaped block, moves to the position of ajar and released, then the pressure inside the block under the action of this increases. aspect. The shape and size of the stress fields depend on the size of such a section and the degree of its deviation from the total length of the bounding fault. The tension level is significantly reduced at the top of the wedge block. Having associated this phenomenon with the localization of mineralization, one may think that, as a rule, there is no mineralization at all in the places of direct junction of faults.

Volcano-structural ore fields and deposits with a predominant influence on the localization of mineralization of volcano-tectonic structures (volcano-structural)

Ore fields and deposits associated with volcanotectonic structures are localized in rocks of a volcanogenic formation - depressions, synclinal troughs and subsidence forms and are associated with large disjunctive disturbances. There are two main types of structures with which ore fields are associated with commercial deposits:

1) ore fields localized directly in the channels of volcanoes arise when the channel of a volcano of considerable size in the transverse (horizontal) section is formed from inhomogeneous eruptive material and is localized among more homogeneous rocks. Joint participation in the tectonic process leads to the development of systems of complex fracture faults and intensive crushing of the host rocks. Mineralization is located inside the volcanic body and is localized along the through faults. Mineralization is controlled by morphological features of disturbances

(bends) and various combinations of feathered structures (adhesion and transverseness). The composition of rocks (lithological factor) is of great importance. Pillar and lenticular bodies predominate on steep and gentle slopes; 2) ore fields and deposits localized in the surrounding rocks of the volcanic structure are formed when the volcanic channel consists of a subvolcanic body (neck) of a homogeneous petrographic composition, while the surrounding rocks are heterogeneous, have stratification elements and are less durable in their mechanical characteristics, which the formation of a subvolcanic body. Tectonic stresses of horizontal extrusion occur in the rocks surrounding the throat in the form of steep and gentle systems of cracks, the combination of which creates a complex tectonic structure of the rock mass.

Mineralization is localized in all systems of split fractures that form morphologically complex ore bodies. Its location is determined by the morphology of cracks and the nature of movement between them. Mineralization occurs with the predominant processes of metasomatism and is located both in the extrusive channels and in the adjacent parts of the faults. In the latter case, the type of mineralization is formed along complex faults. The scale of ore fields is small and medium. The most important factors in the localization of mineralization are tectonic movements, leading to the renewal of faults and walls of volcanic channels, crushing of rivers both inside the craters of paleovolcanoes and in their vicinity. When placing ore fields and deposits of this type, volcano-tectonic formations and deposits are of great importance, among which stand out: 13 - in the domes of volcanoes complicated by disturbances in ascension (Sulukul, Kindyr-Duzakh); 14 - in depressions of volcanoes complicated by faults (Lashkerek); 15 - in calderas complicated by faults (Chakchar, Karasan); 16 - in linear structures of volcanoes complicated by faults; 17 - in peripheral zones and far from the caldera. In general, it is noteworthy that this group has been little studied and not all types have been identified or described.

Contact ores Hills and deposits with a predominant influence on the localization of mineralization of contact structures of heterogeneous rocks (contact)

This group includes ore fields and deposits, mainly associated with the structures of contacts of intrusive rocks between sedimentary and volcanic formations.

The structural features of contact-metamorphic ore fields, including the location, occurrence and morphology of ore bodies, are formed under the influence of many factors: lithology and morphology of the enclosing strata, their occurrence, mutual orientation of contact intrusive surfaces, localization and morphology. In some cases, carbonate rocks develop only in the form of lower layers and lenses of

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volcanic rocks. and terrigenous members of the enclosing strata, in others - the endocontact aureole is composed of almost pure carbonate rocks - limestone or dolomite. The host bedded strata may occur in the form of monoclines, sometimes fractured by folds with different angles of incidence of the wings.

The contacts of the intrusive massif can be consistent with the occurrence of the thickness and inset. Depending on the intensity and depth of faults, in some ore fields there are rare or abundant apophyses of the intrusive massif of various shapes - reed, obtuse, angular, and other intrusions. This causes uneven contact surfaces. In accordance with the mutual orientation of the bedding of the host rocks and the contact surface of the intrusion, as well as the intensity of crushing of the blocks of the host currents, xenoliths of various sizes and shapes can develop in some places of the endocontact zone.

Significant differences are observed in the distribution, size and occurrence of dikes. Ore-regulating factors are interlayer fracturing, interlayer cracking, dike shell, breccia zones, seams and associated fracture fractures. Metasomatic ore bodies (Fig. 5) arise in such different structural and lithological conditions. Tablet contact deposits in concordant (1, 2) and transverse (3-5).

The following are distinguished from the contact ore bodies: bedded contact deposits in the consonant (1,2) and secant (3-5) contacts of the intrusions with the host rocks; bodies of complex shape in complex contacts (6-8); lenses, poles and bodies of irregular shape - in the wings and deflections of synclines (9-10). Contact ore bodies are usually localized in the rocks of contact-metamorphic and intrusive formations. Length from 10 to more than 1000 m, width from 10 to 800 m, thickness from 1 to 300 m.

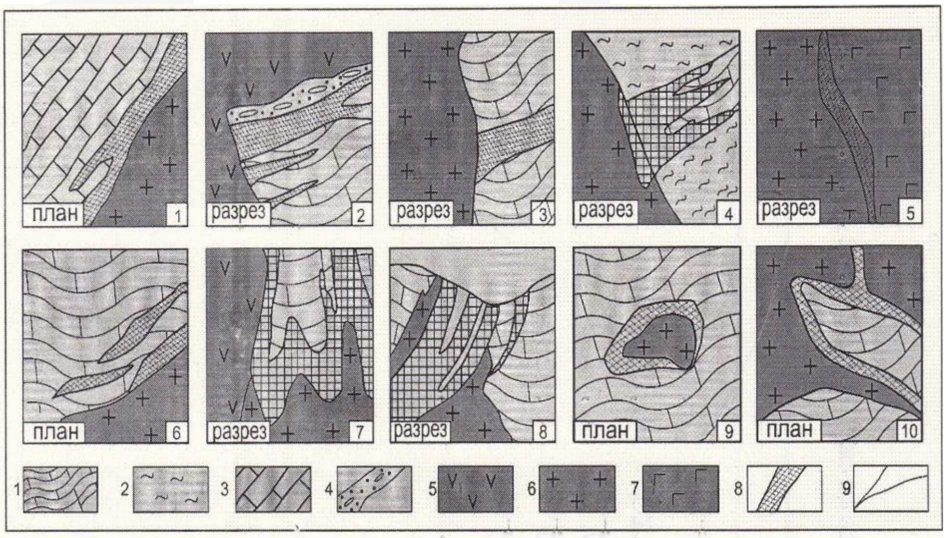

Fig. 5. Structural and morphological types of contact ore bodies.

1 - limestone; 2 - slate; 3 - dolomite; 4 - basal conglomerates; 5 - quartz porphyry tuffs; 6-7 - granitoids; 8 - ore bodies; 9 - malfunctions.

The most productive contacts of intrusions with carbonate rocks. With such a combination, the rocks of the contact-metamorphic formation are formed in certain structural-tectonic conditions, of which rocks are the most favorable for the location of mineralization. This group of ore fields and deposits is dominated by bedded and lenticular contact ore bodies. There are four types of positions: 18 - at concordant and similar contacts of intrusions with host rocks, complicated by faults; 19 - in through contacts of intrusions with host rocks; 20 - along apophyses, dikes and stocks of intrusive rocks; 21 - in the graben and troughs of the roof rocks [1, 2].

18. Ore fields and deposits in conformable and similar contacts of intrusions complicated by faults (Koshmansai, Kainar). A characteristic feature of deposits of this type is the camouflage contact of intrusive rocks with the host strata, intersected by systems of ore-bearing cracks. These contacts tend to have a slight slope. The rocks were formed against the background of the sliding of the roof rocks along the intrusive surface. Therefore, the most favorable are log deflections of the contact surface, intersected by cracks and faults, especially areas with a deep dip towards the sliding of the roof rocks. An important feature of contact ore fields and deposits are different tectonic conditions for localization of rays and mineralization. Rocks are formed against the background of regional extrusion or under conditions of local extension, extending far beyond the area of ore fields.

Mineralization is localized under conditions of regional extrusion under local stretching; therefore, it is distributed unevenly in skarns and is usually confined to those structural positions in which the rocks underwent intense brittle deformation and pre-ore hydrothermal alteration.

19. Ore fields and deposits of through intrusions (Takeeli, Sauleiman-Sai, Bordu, Yangikan, Kantash, Altyntopkan, Uchkatly-Miskan, Kamarsay, Babakan-Zholsay, Aktash, Okurdavan, Orlinnaya Gorka, Kurusai-Dzhangalyk, appear as local ones). in the wings of the large anticlinal structures in carbonate and carbonate-terrigenous formations, contact zones of intrusive bodies, complicated by associated longitudinal-sectional faults. The largest ore fields are formed in the zones of near-contact complex faults as a result of their repeated renewal, accompanied by the introduction of intrusive rock dikes and fender cleats, forming an array of enclosing plate rocks - pockets, which are subsequently replaced by skarns.

Intrusion of dikes and formation of slopes occurs against the background of faults. Skarns are represented by thick contact deposits of considerable length and large vertical range. The deposits are distinguished by complex conditions of mineralization and various morphological types of ore bodies, which are unevenly distributed in the squads, confined to the places of their intensive crushing and changes. Unlike slopes, mineralization is localized at the prevailing thrust faults and strike-slip displacements.

20. Ore fields and deposits along apophyses, dikes and stocks of intrusive rocks. (Tashbulak, Shevchukovskoe, Darbaza, Turangly, Chalata, Salyksai, Kurbankul, Kumishlan) are formed mainly in the rocks of carbonate and contact-metamorphic formations in the wings of anticlinal structures, intersected by longitudinal and obliquely intersecting faults, consisting of small intense bodies of various shapes. genesis. Mineralization can be located both in the contact and in the rocks of the contact-metamorphic formation associated with intrusive bodies. Ore bodies in contact with intrusive ones arise from the contact of intrusive rocks with homogeneous and favorable chemical composition.

Large vertical scale skarn contact bodies. The inhomogeneous composition of the enclosing strata; to the fall, rock bodies are limited by the thickness of favorable horizons, forming belt deposits of considerable length. Skarns were formed against the background of fault movements complicated by minor displacements. Therefore, their thickness increases in the areas of deep immersion of the contact surfaces and decreases with cooling. Mineralization overlaps the rocks and is distributed unevenly in them, being localized mainly in areas of intense crushing and hydrothermal transformation. The position of the crushing zone in the benches is also associated with the morphological features of the contact surfaces of the lying or hanging sides of the zone. The most intense tectonic deformations occur under the influence of those contact areas that were loaded during the existing movements. In the carbonate-terrigenous formation, mineralization is mainly controlled by lithological and structural factors, being confined to horizons of favorable composition, and within them - by the morphological features of contact surfaces and disturbances of the through fracture. The composition of venous changes is important. Ore bodies are represented by simple and complex veins, lenticular beds, ore poles and complex bodies; in carbonate rocks, the contacts of intrusive bodies are accompanied by slopes. Depending on the morphological type of the intrusive body, they form contact bed-forming and lenticular deposits, pole-shaped and enclosing bodies. Their thickness does not exceed several meters. Skarns can arise from contact with apophyses. Mineralization in them is unevenly

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distributed. Ore bodies are localized in places of intense crushing and change of spalls. The localization of mineralization is influenced by the morphological features of the contact surfaces and the nature of tectonic shifts in them. Ore bodies form lenses, nests, pillars, and stockwork zones.

21. Ore fields and deposits in grabens and sinkholes in the roof rocks (Kan, Kurgashinkan) are located in zones of large longitudinal faults saturated with intrusive bodies of basic content. The rocks of the contact-metamorphic formation are mainly represented by intensely serpentine limestones protruding on the deflections of the intrusive roof.

The latter, probably, could in some cases evolve in accordance with the folded structure of the roof rocks, in others they could appear in the form of small grabens bounded by a subparallel fault. Numerous apophyses and dikes, which form an extremely heterogeneous structure of the sites, penetrated into the host rocks. Mineralization is localized at contacts with intrusions and at contacts with dikes. It is controlled by the morphological elements of the contact surface, confined to its smoothed areas. If the remains of carbonate rocks are small, they can change and be replaced by mineralization.

Combined ore fields and deposits (elements of folded and fractured structures, as well as contact structures affect the localization of mineralization (combined).

Combined ore fields arise under a combination of conditions characteristic of simple groups. They are characterized by a complex cross-section, in which rocks of two, three or more formations can be present. As a rule, they are distinguished by the complexity of the tectonic environment, multiple changes in specific deformation plans, and a wide temperature range of mineral formation.

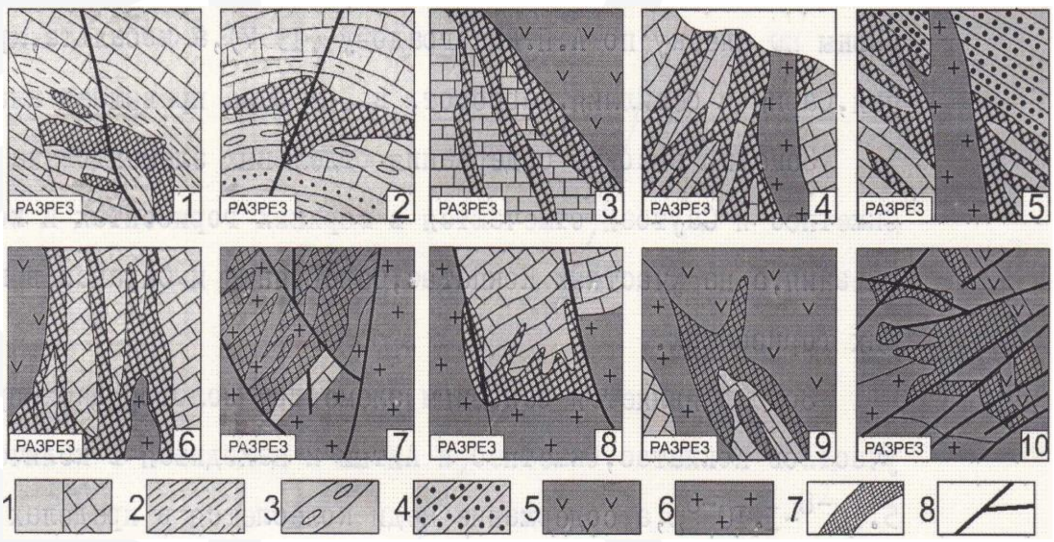

Fig. 6. Structural and morphological types of complex ore bodies.

1 - limestone; 2 - clayey sandstone; 3 - basal conglomerates; 4 - sandstone; 5 - quartz porphyry tuff; 6 - granodiorites, granite; 7 - ore bodies; 8 - malfunctions.

Mineralization is localized as a result of the combined action of several factors. Concordant, contact, and ore bodies of complex morphology are widely developed in the combined ore fields (Fig. 6). Of these, ribbons, lenses, and junction bodies are formed within the layers and are isolated at the dike contacts (1); reniform bodies at fault intersections; favorable horizons (2); contact pillars during transitions along intrusive contact faults (3); bodies of irregular shape at the contacts of dikes and intrusive massifs with host rocks (4-6); bodies of irregular shape in contacts complicated by faults (7-9); ore pillars in the transitions are intrusive and host rocks with a dike (10). Complex ore bodies are found in groups of ore fields in which the main ore reserves are concentrated. Length - 5-500 m, width - 10-250 m, thickness - 1-30 m.

Of the combined ore fields and deposits, two types are distinguished: 22 - in blocked horst-anticlines and graben-synclines; 23 - in highly compressed anticlines complicated by faults with the formation of a folded-block structure [1, 11].

22. Ore fields and sediments in blocked horst-anticlines and graben-synclines. (Uchkulak, Paybulak, Kansai). A characteristic feature of the section is the presence of three formations - carbonate, carbonate-terrigenous and contact-metamorphic. The first two show different combinations. In a folded structure, they are located in the wings of large anticlines and in all known cases are confined to places of bends in plan.

Ore fields are located in blocks between adjacent subparallel, axial or intersecting faults.

A narrow horst-anticline usually occurs under conditions of horizontal compression, usually oriented to extensional faults, under the action of blocking by carbonate and carbonate-terrigenous formations elongated along the stratification. Multilevel chips are formed; they are accompanied by crushing, development of intersection disturbances and intrusion of conformable dikes of intrusive rocks. Complex ore bodies are formed with a predominance of concordant elements. At the base of the carbonate formation, the conditions of deformation of the former are sharply changed. When blocked by longitudinal faults that are not covered by hard rocks, limestone easily turns into a steep, tightly compressed ant: the wedge breaks off from the solid base. Numerous chips appear in the wings and axial parts of the fold, which are accompanied by crushing. Blocking faults serve as access channels. The scales of ore fields and deposits of this type are different.

23. Ore fields and deposits in large compressed anticlines complicated by faults with the formation of a folded-block structure (Aktyuz, Kutessay II) [1, 2, 6, 8]. Strongly compressed ore-bearing anticlines are located in the flanks of large anticlinal structures. Usually they are represented by folds of the 2nd and 3rd orders, limited by longitudinal faults, protrude in the places of bends of these structures in plan and are accompanied by waves of axes.

In the axial parts of the folds of the shale formation, there are extended intrusive massifs of the central type, which are also accompanied by dikes. With a combination of shale and intrusive formations, mineralization is localized along the contact surface and in shales. Its location along the contact is controlled by those areas of the contact surface that were weakened and released from deformation during the period of mineral formation. In shales, ore bodies are localized in the stocks of granophyres, confined either to diatremes or to places of disintegration in each tectonic block, depending on particular plans of deformation. In carbonate strata, mineralization is localized in horizons of favorable composition, confined to areas of their intense crushing (axial parts of folds, small intersectional faults, their various sections). Concordant, transverse, and composite bodies appear, the sizes of which vary over a wide range.

CONCLUSION

All known polymetallic ore fields and deposits of the Tien Shan are combined into five geological and structural groups, within which 23 types are distinguished.

In folded ore fields and deposits, the dimensions of folds, lithological features of the section - rocks with contrasting signs of deformation, horizons suitable for selective mass crushing, the presence of dense rocks capable of creating long-term storage of large volumes of protective and crushing cavities.

Large deflections of folded structures, the nature of their relationship with large faults and the factor of blocking folds by linear faults are essential. In folded ore fields and deposits, mineralization is localized in layers of layered rocks of heterogeneous lithological composition.

In fracture structures, their morphology, kinematics, and physical and mechanical properties of rocks are of decisive importance. The volumes of deformation depend, first of all, on the morphological elements of the faults, under the influence of which tectonic stresses have arisen in the host rocks, which determine the nature and intensity of deformation.

In contact ore fields and deposits, the localization of mineralization is determined by the morphology of contacts of intrusive bodies with the host sedimentary-metamorphic complexes.

Thus, the methods of structural analysis of ore fields and deposits represent one of the important components of the general methodology for the development of detailed and large-scale geological forecast maps and open up opportunities for a quantitative assessment of the forecast reserves.

Geological and structural studies are important for understanding the genesis of deposits and the processes of ore formation.

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