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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy
of Earth sciences

GEOLOGICAL STRUCTURE AND ORE BEARING OF THE TALACHAY-KURMUKCHAY SECTION OF THE SARIBASH STRUCTURAL-FORMATION ZONE (SOUTHERN SLOPE OF GREATER CAUCASUS)

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INTRODUCTION

Relevance of the work. The discovery of Filizchay, Katekh, Kasdag and other colchedan-polymetallic deposits on the southern slope of the Greater Caucasus is proof of the area's prospects.The Sarybash structural-formation zone is one of the main ore-bearing structures of the southern slope of the Greater Caucasus, and is considered one of the most promising areas in the region in terms of colchedan-polymetallic deposits and manifestations. For this reason, the study of the localization feature, conditions of formation and regularity of distribution of kolchedan mineralization is one of the relevant issues for the analysis of the considered area and the theory of mineralization as a whole.

The purpose and tasks of the research. The main objective of the research was to study the geological structure of the Talachai-Kurmukhchayarasy section and to determine the kolchedan ore bearing formation in the Lower Middle Jurassic age complexes.To achieve this aim, it has been planned to:

1) study of the geological structure of kolchedan-polymetallic mineralisation, determination of regional and local geological-structural factors of localization of mineralization, study of communication with the regions of volcanism development;

2) study of the composition and structure of ore-bearing facies, separation of lithological-stratigraphic horizons and assessment of their role in the localization of mineralization;

3) study of the morphogenetic characteristics, material and mineralogical composition, structural-textural aspects of ore piles reflecting the ore accumulation conditions of the geological structure of colchedan-polymetallic mineralization;

4) determination of the geochemical properties of ores - the role of the Indicator of the distribution of the amount of the main ore elements and elemental compounds in clarifying the physico-chemical conditions of the mineralization process and the geochemical environment;

5) Evaluation of prospectivity of kolchedan-polymetallic and other genetic mineralization in the section between Talachay-Kurmukchay.

Factual material and research methods. The basis of the dissertation was the author's actual material and camera studies collected during field expeditions in 1996-2018, as well as the analysis of stock and printed literature materials.The claimant has described Lower-Middle Jurassic outcrops sediments, more than 50 km of search mapping routes have been made, different types of kol-chedan mineralization located in the Talachay-Kurmukhchayarasi section have been studied.The results of the obtained geophysical, geochemical and slice analyzes were interpreted, and the relationship of mineralization with specific lithological-facies complexes was determined. A 1:200,000-scale geological map of the southern part of the Greater Caucasus (with the regularity of mineral deposits) was compiled by the author.More than 50 anslice, 230 slice descriptions belonging to the author, about 500 spectral, 20 silicate, 11 isotope X-ray-structural analysis results of rocks and ores were used.The analyzes were carried out by applying modern research methods in the relevant laboratories of the National Geological Exploration Service, the Caucasian Institute of Mineral Raw Materials (Tbilisi) and the Institute of Geology and Geophysics of ANAS."GIS" and "Corel Draw X6" software packages were used in the processing of graphic materials.

Scientific novelity of the work 1) The geological and tectonic structure of the Sarybash and Dabalt ore fields and the location of mineralization have been revealed;

2) In the Talachay-Kurmukhchayarasi section, the upper-lower aalene level of the localization of potential sulphide mineralization was determined in the cross-section of the mineralization shale layer, and their genetic connection with hydrothermal-sediment and epigenetic hydrothermal-metasomatic process was determined;

4) the faults at the site of mineralization were characterized, the temporal and spatial relationship of rift tectonics with folds, and their role in localization were determined;the main ore-bearing lithologic-stratigraphic levels of the Lower-Middle Jurassic deposits were determined, areas of Kolchedan-polymetallic mineralization with

prospects of industrial significance were identified, and their affiliation with specific strata was established;

4) It is shown that ore-bearing stratigraphic horizons predominantly occur in silty-clayey and clayey layers.

5) A 1:200,000 scale geological map of the Azerbaijani part of the southern slope of the Greater Caucasus (with the location regularities of mineral deposits) has been prepared in the electronic version.

The practical relevance of the work. The regularities of pyrite-polymetallic mineralization have been established, and the existence of three horizons bearing pyrite-polymetallic mineralization has been substantiated.

The developed prospecting and forecasting criteria for the discovery of promising areas and new types of ores were transferred to the National Geological Exploration Service of the Ministry of Ecology and Natural Resources.

Main defending statements:

1. Belonging to the lithological-stratigraphic levels and specific layers of pyrite-polymetallic mineralization of the Talachay-Kurmukhchayarasi section of the Sarybash structural-formational zone;
2. Multi-stage formation of pyrite-polymetallic deposits, manifestation of gold-silver mineralization;
3. Lithological and structural conditions of ore formation, paragenetic connection with magmatism, geochemical characteristics.

Publication of the work and və scientific publications. The main results and provisions of the dissertation work were reported at republican and international conferences. There were published 19 scientific publication (14 articles, 5 abstracts of conference and thesis), also 2 articles in periodical scientific journals recommended for the award of an academic degree and scientific degree in Earth sciences, 2 articles in journals included in the Web of Science database of Clarivate Analytics).

Structure and volume of work. The dissertation work consist of an introduction, 5 chapter, conclusion and recommendations, a list of cited literature, including 159 titles, 24 figure, 9 table. The total volume of work is 186 pages (general volume 239314 characters, also part of introduction 5650-characters, 1st chapter-17946; 2nd chapter

-62456 characters; 3rd chapter-23424 characters; 4 th chapter-107443 characters; 5th chapter-19640 characters, conclusion and recommendations-2755.

The dissertation work was carried out under the scientific supervision academian department of Mineral resources of Baku State University of Ministry of Science and Education of the Azerbaijan Republic.

BRIEF SUMMARY OF DISSERTATION

Chapter I. Position of the Greater Caucasus in the Alpine-Himalayan fold system and spatiotemporal location of endogenous polymetallic mineralization. 1.1. In the Greater Caucasus, the Alpine-Himalayan fold system. Metallogeny of the Greater Caucasus, geology and genesis of its individual deposits is considered in the works of V.B.Agayev, V.M.Baba-zadeh, T.N.Kangarli, H.A.Valiyev, V.N.Naghiyev, N.A.Novruzov, S.A.Agayev, J.S.Mazanov, S.F.Vali-zadeh, A.Sh.Shikhalibeyli, A.G.Zlotnik-Khotkevich, H.A.Chalabi, CH.M.Khalifazadeh, V.Y.Khain and many others. One of the main features of the regional location of the Greater Caucasus is that it is associated with the recent activity of the Arabian Plate. In the eastern segment of the orogen in the north-northeast direction, the East Taurus, Pontian and Lesser Caucasus complexes are noted, repeating the summit protrusion of the Arabian Plate. Since the latter developed as a continuous complex of folds in the Meso-Cenozoic cover, probably that it represents the latest, modern developing structure. The lithospheric suboceanic microplates of both basins played a role in the formation of this structure, which occupies a "corridor" position between the Black Sea and South Caspian basins.

What has been shown allows us to come to the conclusion that from the Pliocene to the present, the Greater Caucasus has developed under two different dynamic conditions[1]. Its eastern segment, the junction between the Black Sea and the Caspian Sea microplate, was influenced by the northward-shifting Arabian Plate and was under meridional compression. In terms of the distribution of geodynamic changes and morphology, the eastern segment of the Greater Caucasus, connecting to the Arabian Plate, and the Taurus, Pontic and Lesser Caucasus geoblocks adjacent to it from the south have much in

[1] Prutsky N.I. Zone of accretionary folding of the Southern slope of the Greater Caucasus / Problems of assessing geology, forecasting mineral reserves in the south of Russia. Abstracts of reports of the Zonal Scientific Conference. Novocherkassk, 1995, p.11-13.

common with the structures of the Himalayan Plate-Pamir ridge of the Alpine-Himalayan belt. Based on this feature, the late Alpine stage of tectonic development of the eastern segment of the Greater Caucasus can be considered Himalayan.

1.2. Position of endogenous mineralization in spatiotemporal boundaries. The Greater Caucasus is one of the lineaments of the Alpine-Himalayan fold belt and is characterized by significant mineralization. There are a number of deposits and manifestations of non-ferrous, rare, radioactive and precious metals, as well as hydrocarbons and hard coal. Large deposits of ore minerals of industrial importance are of endogenous origin.Among them, in particular, the groups Tirniauz (Ẁ, Mo), Sadon (Pb, Zn, Ag) and Urup (Cu, Zn, Au), Hudes (Cu, Co, Au), Gizil-Dera (Cu, Co), Filizchay (Pb, Zn, Cu), Katsdag (Pb, Zn, Cu), Kti-Teberdinskoe (Ẁ), Beshtaugorskoe (U) deposits.

The formation of large endogenous ore deposits is associated with three main epochs of metallogenic development of the Greater Caucasus: Hercynian, Early Alpine (Cimmerian) and Late Alpine. The location of ore fields corresponds to different geodynamic conditions. Sediments of each epoch considered separately were formed in two stages: basinal accumulation of pre-orogenic strata and orogenic-collisional one. In the Hercynian and First Alpine (Cimmerian) eras, the mineralization process was clearly evident in both eras, while in the Late Alpine era only deposits of the orogenic phase were developed.

Chapter II. Zoning of the Jurassic-Cretaceous sediments of the Sarybash structural-formation zone of the southern slope of the Greater Caucasus.

2.1. Jurassic system. Upper Toar. The Upper Toarcian is composed of clayey rocks (slaty and clayey shales, siltstones) and alternating small rhythmic sandstones. Its total thickness is 1000-1500 m. Lithologically and paleontologically, these rocks are so difficult to separate from the lower layers of the Aalenian that they are considered as a single complex. This complex was identified by V.B.Agaev[2] and

[2] Agaev V.B. Stratigraphy of Jurassic deposits of the Azerbaijani part of the Greater Caucasus: Abstract of thesis. ...Dr. geol-min.sciences.. Baku, 1979, 45 p.

A.Sh.Shikhalibeyli[3] as the Megakan Formation and is widespread in the middle reaches of Mazimchay, Balakenchay, Megikanchay and Katekhchay.

Middle Jurassic. Lower Aalenian. Mazymchay-Katekhchayar-asi is widely developed and is divided into two layers: conglomerate-siltstone (58-70 m) and sandy-clayey (105-280 m). In the Kurmukchay basin (Khurai Pass) V.B.Agaev[2] discovered the Lower Aalenian fauna Leioceras sp. Comptum Rein, as well as large numbers of *Mytiloides sp.* The thickness of the lower layer here is 163-350 meters. In the lower Aalenian deposits there is a layer of siderite sandstone. *Middle Aalenian.* In contrast to the underlying formation, sandstone strata play an important role in it, connected to the clay layer, sometimes by gradual transition and sometimes by tectonic contact.

Upper Aalenian deposits can be traced from the meridian of Mount Binovrassa in the west to Mount Tufan in the east.

The upper Aalenian is exposed in the upper reaches of Bala-kenchay, Katekhchay, Talachay and Mukhachchay[4]. Small-sized *Ludvigia subtilicostac* Krimti., L.cf.rudis Buckm., belonging to the upper Aalenian, are collected here.[2] The lower *layer of the Bajocian* is less common than the underlying Aalenian deposits.

Upper Jurassic. The Upper Jurassic sediments are in marked contrast to the underlying ley and Dogger age sandstone and shale lay-ers. A distinctive feature of the *Malm* deposits is the stability of the composition of the layers throughout.

The stratigraphic units assigned to the Upper Jurassic are Kim-meridgian and Tithonian in age. The deposits of the Kimmeridgian stage are known as chert rocks or the Zemchay suite[5]. The Kim-meridgian is conformably overlain by the red rocks of the Lower

[3] Shikhalibeyli E.Sh., Karabanov V.V. Geological structure of the Durudja suture zone in the eastern part of the southern slope of the Greater Caucasus (interfluve of Vandamchay and Akhokhchaya) // News of the Academy of Sciences of the Azerbaijan SSR, series of Earth Sciences, 1979, No. 2, p. 24-28.

[4] Geology of Azerbaijan. T.I, Stratigraphy, Baku: Nafta-Press, 2007, 580 p.

[5] Shikhalibeyli, E.Sh. Geological structure and development of the Azerbaijani part of the Greater Caucasus / E Shikhalibeyli, - Baku: ed. Academy of Sciences of the Azerbaijan SSR, - 1956. - 224 p.

Tithonian or is in tectonic contact with the massive calcareous sandstones of the Upper Tithonian.

Subdivisions of the *Tithonian stage* are characterized by their names depending on the facies within the southern and northern slopes of the Main Caucasus ridge: *sudur, shahdagh, ilisu, kyzylkirma.*

2.2. Cretaceous system. The transition of terrigenous Jurassic deposits into Lower Cretaceous carbonate deposits is visible.This is largely due to the radical restructuring of physical-geographical conditions and climate during the peneplainization of the land. Cretaceous deposits in the study area have a wide distribution area from the Central anticlinorium to the south.The Valanginian layer is represented by the Babadag layer on the southern slope of the Main Caucasus Range [5] .The Turonian- Coniacian stage consists of siliceous rocks stratigraphically located above the tuffaceous layer.The layer forms the central part of the Gakh synclinorium and participates in its structure. The layer is visible only in a few places and in most cases is covered with Quaternary sediments.

Chapter III. Tectonic development and ore-controlling structures. Within the region, several first-order structures are closely oriented: To the north and south are the Tufan and Kakheti-Vendam anticlinors, respectively, and the large Cretaceous Zagatala-Khovdag flexure lying between them. These structures are separated from each other by deep faults and, in turn, are fragmented at lower levels. On the border of the Tufan anticlinorium and the Zagatala-Govdag synclinorium, the Mechekhchadaur deep fault zone with an anticlinal structure is also identified. The following structural elements are identified in the study area. Some of them are structures that control mineralization. Sarybash tectonic stage. According to the morphogenetic characteristics of fold-fault structures, the tectonic stage consists of three transversely folded structures that form a stepwise transition to each other along large thrust-uplifted zones. *The second-order northern transverse stage* covers the Karasu River basin and is located in the northeastern part of the region where research work is being carried out. *The secondary southern longitudinal* step is limited from the north by the Sarybash fault. Along the deep fault, Aalenian sediments overlie Bajocian sediments, and the fault is considered a western extension of the Malkamud uplift. Axial faults, that is, faults running along the axial surface of anticlinal structures, have a larger area of distribution. Along rigid ridges and their branches, the angles of occurrence of not only rocks, but also faults range from 20-40° and increase to 60-80° as the erosion area deepens. *The Khutor fault zone* is the northernmost zone in the study area, starting from the mountain of the same name, passing through the village of Suvagil and the Garasu River and can be traced in a southeastern direction. Karachay fault. It can be traced along the valley of the river of the same name and consists of the western continuation of the fault, called the Mechekh fault. Along this fault there is a contact between Bathonian sediments and Upper Jurassic (Kimmeridgian) sediments. The fault is an important tectonic feature not only in the study area, but also in the region. Along this fault, various horizons of the Middle and Upper Jurassic are in tectonic contact. Due to their structural and genetic characteristics, the pyrite-polymetallic deposits of the southern slope are controlled by longitudinal hidden or transverse displacement faults relative to the fold[6]. *Transverse structures:* M. A. Gashgai (1967), V. Ya. Khain (1984), B. M. Isaev (1972), Kh. G. Gurbanov (1986) noted the important role of transverse structural blocks in mineralization. At the present stage of research, the following first-order transverse blocks are distinguished: Balaken-Gakh, Gabala-Ismayilli uplifts and Sheki depression blocks.

Each of these blocks is divided into lower grade stepped transverse blocks. For example, the Balaken-Gakh block consists of three low-grade blocks, of which the Balaken and Gakh blocks are high-grade, and the Zagatala block is a low-grade block.

The area of our research is located on the Gakh block of uplifts, which consists of systems of uplift and descent microblocks. When identifying microblocks, the author took into account the following aspects: as they approach the boundaries of the transverse uplift blocks, these structures lie rigidly, become buried or take on a bend-

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[6] Isaev, B.M. The role of tectonics in the localization of pyrite mineralization in the Belokano-Sheki pyrite province: / Abstract of thesis. Ph.D. geol.-min. Sciences: / - Baku, 1972. – 26 p.

like structure, strongly bend and unfold; longitudinal folded structures are often branched, and their hinges are rigidly fixed; The branching and burial of the folds coincide with the strip where bends and cracks develop in the transverse fault structures. A sharp change from shallow-water facies to deep-water (or vice versa) is observed at the boundaries of upwelling and downwelling areas. The phyllising layers were subjected to intense deformation. They clearly distinguish two types of cleavage:

1) flow cleavage that develops along the axial surface of folds during the growth of wrinkles, and 2) continuous cleavage that accompanies many thrust and thrust systems.

Chapter IV Geological and genetic characteristics of coal mineralization on the southern slope of the Greater Caucasus.

4.1. Brief geological and structural description of pyrite-polymetallic and copper-pyrrhotite deposits of the Sarybash structural-facial zone. The main features of mineralization in the zone are the following: 1) localization of mineralization in the section of siliceous-coal-carbonate-shale sedimentary rocks; 2) that ore masses usually have a suitable layered character; 3) the peculiarity of sedimentation of pyrite-polymetallic ores (wide development of layered texture and metacolloidal structural forms); 4) "contamination" of the ore-bearing strata with dispersed fine-grained syngenetic sulfide mineralization; 5) simple mineral composition of ores; 6) metasomatic change of weak ores of rocks at the contact of ore masses and intra-ore plates. All these are facts in favor of the syngenetic feature of sedimentation of ore matter. The relatively homogeneous facial appearance of the ore-bearing strata, the massiveness and compactness of the ores indicate a local source of ore material, and the metacolloid nature of the mineral aggregates indicates a high concentration of ore solutions.

The deposits of the Sarybash structural-facial zone can be attributed to polygenic and polychronous Kolchedan deposits of hydrothermal origin. These types of deposits are localized in carbonate-shale formations and are located quite far from the centers of volcanism, synchronous with the mineralization process[7,8].

4.1.1. Sarybash copper deposit and copper-polymetallic deposit. The Sarybash deposit is administratively located on the territory of the Gakh region, in the upper reaches of Kurmukchay, within the boundaries of the structural-facies stage of the same name around the village of Sarybash. The thickness of the Upper Toarcian deposits here is 300 m. Layers of the lower and upper floors Upper Aalenian (J_2a^3) are composed of siderite conglomerates and shales and are distributed in the arch part of the Sarybash anticline with a thickness of 200-400 m. Structurally, the Akhvai anticline, Khurai syncline and Saribash anticline were formed in the Sarybash zone. The folding of the territory is aggravated by tectonic faults. Intrusive rocks consist of gabbro-diabase and diabase.

The ores of the Sarybash deposit are polymetallic (Cu, Pb, Zn) deposits of the Filizchay type, containing noble metals (Au, Ag)[9]. Three types of mineralization are observed at the deposit: the first type of mineralization is observed along the bend of the Sarybash fault. This fault zone consists of limonized, eroded, sometimes black pyrite grains found at the intersection of young frictional clay faults. In samples taken from them, Au-0.5-2.8 g/t and Ag-4-5.60 g/t were found. The second type of mineralization consists of aggregates of pyrite, chalcopyrite, sphalerite and galena. This type of mineralization formed large boudins and layered lenses in two zones of the Saribash fault, the thickness of which in some places reaches 12 m. Minerals derived

[7] Ganbarova E.F., Nazarova R.R. Prospects for identifying new deposits of pyrite ores in the Sarybash structural-formational zone (Southern slope of the Greater Caucasus) // News of the Siberian Branch of Geosciences of the Russian Academy of Sciences. Geology, exploration and development of mineral deposits Vol. 40, № 3, 2017, 35p.

[8] Ganbarova E.F. On new promising deposits and ore occurrences on the southern slope of the Greater Caucasus (Azerbaijan) // Bulletin of the Vladikavkaz Scientific Center. V.21, №2, 2021, c.

[9] Kurbanov N.K. Conditions for the formation and patterns of placement of stratiform pyrite-polymetallic deposits of terrigenous eugeosynclines (using the example of the Alpine province of the Greater Caucasus): Author's abstract. diss. ... Doctor of Geol.-Min.Sc. M.: 1986, 49 p.

from sulfides (limonite, malachite, azurite) are found in the contact of ore massifs with side rocks. In samples taken from the zones, Cu - 0.1%, Zn - 0.2%, Pb - 0.06%. The third type of mineralization is represented by ore veins, observed with an uneven distribution of pyrite and pyrite-siderite nodules in the rocks. They have variable thickness (0.3-1 cm) and can be traced at a distance of 2-3 m. The first and second zones are interesting from the point of view of ore content.

As a result of field tests, a slag sample was taken every 5-10 m in areas where Au and Ag were obtained at 1-2 g/t and where rocks from these areas may be subject to washout and erosion.

At the same time, about 5,500 geochemical samples were taken from ore zones, tectonic fault zones and various types of rocks. The results of the tests showed that in the western extension of the Sarybash mineralization area, two more zones with indicators of Cu, Zn, Pb, Au and Ag elements many times higher than the background amount for the area are separated from the place where the main zones are defined.

The mineralization area consists of 2 zones traced over a large area where relatively poorly mineralized two-prospective gold-copper-polymetallic ores were discovered. Here, predicted resources of copper, lead and zinc with P_1 category were calculated. In these ore zones, copper amounts to 0.01-2.8%, lead 0.01-0.95%, zinc 0.01-2.0%.According to the forecast indicators noted in the first zone (L=7800 m, D=500 m, m=6.3 m, d=3.5 t/m3, Cu=0.22%, Pb=0.54%, Zn =1.27%) 189.2 thousand. 464.4 thousand tons of copper, 464.4 thousand tons of lead and 1092.1 thousand tons of zinc were identified. The predicted resources of gold and silver in the P_1 category zone were also calculated (L=8000 m, D=500 m, m=6.0 m, d=2.7 t/m3; Au=0.86 g/t, Ag=14 , 01/i.e.

Magnetic exploration work (grid 100x10 m) using the CAPG method (grid 100x20 m) and special geophysical work in VES Av-1500 m (with route) were carried out at the field site.

4.1.2. Dabalt colchedan and copper-polymetallic deposit. It is discovered in the eastern part of the Katekh-Gumbulchay structural-facies zone. The ore zone is located 300 m southwest of the height of 1908.5 m, 425 m east of the height of 1856 m in the southwestern part of the Dabalt ridge. The geological structure of the deposit includes siderite and cimi (gymy) formations. According to the lithological composition, the rocks are composed of dark gray black shales alternating with thin-layered medium-grained sandstones. (fig. 1) The layer corresponds to the axial part of the anticlinal fold, bounded by the north-trending Khamzagoren uplift and extends along faults. Here the side rocks are crushed, silicified and ferruginized. Mineralization is represented by dense, stringy content. Ore minerals consist of earthy aggregates of galena, pyrite, and derivative minerals. The thickness of the ore veins is 1.5-5.0 cm, the thickness of the ore zone is 4.5-5.0 m. The zone is traced for a distance of 75 m, and then covered with a thick layer of alluvial and colluvial deposits in the eastern and western directions. According to the results of chemical analysis, the amount of useful components is as follows: Cu - 0.06%, Zn - 0.02%, Pb - 10.76%, Mg - 0.002%.Samples were taken from the oxidation zone. The length of ore layers at the Dabalt deposit is 1000 m on both sides, the depth of mineralization is 300 m, the average thickness is 5 m, the average content of Cu is 0.3%, Zn and Pb are 3.5% each. Ore zones are characterized by large intervals of gold and silver content. In this case, the amount of Au in the samples reaches 4-5 g/t or more. Au was not found throughout the entire zone. Significant amounts of this element, as well as Ag, are observed in the central part of the zone. From the eastern margin of the zone to the middle zone, the thickness of the gold and silver intervals ranges from 3-5 m to 10-12 m, and the total continuous length of the mineralization interval is 2.3 km. The shale layer shows signs of Au. Even in these rare cases, gold mineralization is at least partially related to quartzization.

The samples revealed gold, silver, cinnabar and other precious minerals. Areas (Kavalachay, Dabalt, Suvagil) where certain signs of pyrite, chalcopyrite and sphalerite minerals are more common, having a certain search sign, were separately explored, and the territory was assessed as promising.

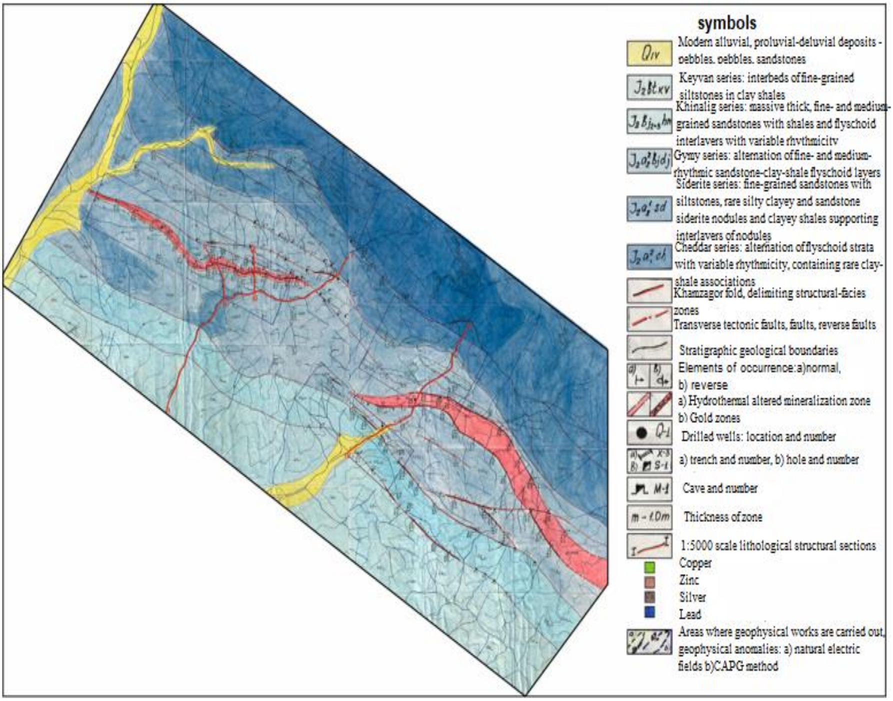

Figure 1. Geological map of Dabalt colchedan and copper-polymetallic deposit. Scale 1:10000. Compiled based on the materials of the Main Caucasus GEE: E. Ganbarova.

4.1.3. The Suvagil colchedan-polymetal manifestation is located east of the Dabalt deposit and has a kind of conventional border with it. The geological structure of the deposits is similar, the ore-controlling tectonic faults pass directly from one to another, the characteristics of the zones are identical. The area of the deposit contains deposits of siderite, cimi (gymy)and khynalyg. They are cut by acute-angled tectonic folds of predominantly northwestern strike. During the faulting, the rocks underwent hydrothermal alteration, intensive crushing, ferruginization, silicification and sulfidation. Gold and silver mineralization is directly associated with these zones.

4.1.4. The Kavalachai colchedan-polymetal manifestation covers the right bank of the river of the same name. In the geological structure of the occurrence, the header layer, which belongs to the lower part of the aalenian, consists of sediments (alternating flyschoids with different rhythms and shales with rare nodules).Small amounts of Ag (1-2 g/t) in alteration zones associated with tectonic faults and 0.1 g/t Au were determined in one sample taken from altered shales.

4.1.5. The Khutor manifestation is an intensely hydrothermally altered zone of rocks located on the southern slope of the Khutor ridge (2844 m) in the upper reaches of the Karachay River. The geological structure of the area includes deposits of clay-siderite and sandy-shale layers. Clay shales are brown, ocher, black, whitish, cracked. Thickness of the upper zones change from 0.8 m to 3.0 m and are observed in one stripe as they move away. The band coincides with the Karasu manifestation in the eastern direction. Chemical analysis of groove samples taken from the surface of the earth showed that the amount of useful components is not very large: Cu-0.09%, Zn-0.07%, Pb-0.05%, Au-not detected. Only experiment No. 395 showed a relatively high amount: Cu-0.15%, Zn-0.7%, Pb-0.9%.

4.2. Morphological types of ores. Pyrite-polymetallic mineralization was represented by 4 morphological types depending on the interaction with the side rocks: 1) massive ore masses with jointly occurring lenses and stratified bands; 2) suitable layered and cutting stockwork-breccia (porous-network) ores; 3) ore massifs located in the tectonic contact of magmatic vein masses with side rocks; 4) pyrite concretions, pyrite-siderite and siderite formations. Ore masses are apparently located along shale-layered surfaces in monoclines or on the wings of isoclines, elongated in a northeast direction, have a slight slope (25-35°), sometimes form swellings and lie at great depth. Tension directions follow in horizontal sections. The interaction of ore massifs with side rocks is expressed in the following 3 forms: 1) pure ore-clay shales; 2) pure ore-quartz-sulfide veins, cut by a network of clayey shales; 3) breccias of acute-angled fragments of hornblende shales in a pure ore-quartz-sulfide-cemented aggregate.

4.3. Mineral composition and typomorphic elements of ores. Mineral associations and stages of mineralization. Structural and textural characteristics of ores. Source of ore matter.

4.3.1. Mineral composition and typomorphic elements of ores. Most pyrite-polymetallic and copper-pyrrhotite deposits are similar in mineral composition and geochemical characteristics[10,11,12,13]. Ores usually contain 20-30 minerals. In large and well-studied fields (Filizchay, Kizil-Dera, etc.) their number is 40 or more. Practically, the composition of primary and secondary minerals of colhedan-polymetallic and copper- pyrrp yrrhotite mineralization in all deposits is the same: chalcopyrite, sphalerite, pyrrhotite, pyrite, magnetite, sometimes galena and arsenopyrite, quartz, sericite, carbonates. Rare and sporadic minerals are also similar.

The main feature of the pyrite ores of the Sarybash structural-formational zone is that they are rich in copper. If in colhedan-polymetallic deposits copper occupies a dependent position, then in pyrrhotite-type deposits it predominates and is represented by chalcopyrite. Associated with this mineral are cubanite, vallerite and bornite. The presence of cubanite and vallerite, which are products of the decomposition of chalcopyrite, indicates that the temperature of formation of this mineral was in the range of 350-250°C. Pyrite mineralization forms the bulk of pyrite-polymetallic ores and occurs from latent crystallinity to medium-grained aggregates,forming kidney-

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[10] Veliev G.A. Localization conditions and material composition of copper-pyrrhotite ores of the Zhikhikh ore field. Author's abstract. diss. ...candidate of geological-min. Sci. Baku,1985, 25 p.

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[13] Tvalchrelidze A.G. Geological and geochemical conditions for the formation of massive deposits: Author's abstract. diss. ...doc.geol.-min. Sci.M.: 1983. 45 p.

shaped, lenticular, lenticular-vascular, concretionary, and spot-concretionary forms. Genetically, three types of pyrite mineralization are distinguished: 1) diagenetic; 2) metamorphogenic and 3) hypogene[9].

The following types of ores have been identified in the Sarybash ore field:1) massive specific type of pyrite; 2) brecciated, mottled-rich pyrite type with variegated concretion and lenticular-massive type; 3) type expressed by stockwork-vein pyrite-chalcopyrite-sphalerite-galena ores. The distribution of elements in these types of ores is different. If in the first two types iron and sulfur associated with pyrite predominate, and zinc is slightly less, then, on the contrary, the amount of iron and sulfur in vein ores decreases sharply, the amount of zinc decreases slightly and the amount of lead increases. Copper is present in small quantities in all ores. (table1).

Table 1

The total of the distribution of elements in different types of ores of the Sarybash deposit

Components	unit of quantity	Specifically for the massive pyrite ores			Breccia-colored pyrite-related ores heir and lens ore			Stockwork with veins pyrite-chalcopyrite-sphalerite-galena ores		
		min	max	medium	min	max	medium	min	max	medium
Pb	%	3.78	11.0	5.57	1.01	6.80	2.69	0.311	28.60	3.47
Zn	-"-	3.10	8.90	6.53	1,02	5.73	2.99	0.28	10.90	2.14
Cu	-"-	0.28	0.75	0.4	0.14	0.51	0.32	0.10	1.68	0.30
S	-"-	13.8	40.5	35.0	4.00	25.1	13.4	1.00	15.20	8.6
Pb+Zn+Cu	%			12.55			6.00			591

4.3.2. Mineral associations and stages of mineralization. There are 3 main stages of mineralization of pyrite-polymetallic deposits: 1) layered, banded and massive sulfur pyrite ores of hydrothermal-sedimentary origin; 2) pyrite-copper-polymetallic ores of hydrothermal-metasomatic origin; 3) copper-pyrrhotite ores. At the last stage, pyrite was replaced by pyrrhotite and magnetite, which indicates a widespread manifestation of the process of hydrothermal metamorphism.[10,14,15]. In the formation of copper-pyrrhotite deposits, 3-5 stages of mineralization are also distinguished[11]. Depending on the presence of primary and secondary minerals, different types of minerals are distinguished. Thus, the chalcopyrite-galenaite-sphalerite-pyrite-pyrroite type typical for the Kasdagh copper-pyrrhotite deposit contains 1.5-2% chalcopyrite, 1.5-4% galena, 3-6% sphalerite; pyrite is largely subordinate to pyrrhotite (1:6-8).

4.3.3. Structural and textural characteristics of ores. Ore structure. Based on the morphological appearance, hypidiomorphic granular, allotriomorphic granular and porphyritic structures are distinguished.

According to the texture of the ores, vein-massive, concretized, sparsely scattered, finely speckled-lens-concreted, linear-layered and massive types are common.

4.3.4. Source of ore matter. Based on the isotopic composition of sulfur, the coal-polymetallic ores of the Greater Caucasus are divided into three classes:1)pyrite nodules and scattered inclusions in shales (range of δS^{34}‰ fluctuations from +3 to +15); 2) small deposits and manifestations of hydrothermal-sedimentary and metagene-regeneration type (fluctuation limit δ S34‰ +3+8.3); 3) large pyrite deposits of the region – Filizchay and Gyzyl-Dera (fluctuation limit δS^{34}‰

[14] Aliev G.I. Structural conditions of localization and patterns of placement of pyrite-copper-pyrrhotite deposits of the Belokano-Zakatala ore district (Zhikhikh-Chugak ore-bearing zone): Author's abstract. diss. ... Candidate of Geol-Min.Sc. Baku,1972, 25p.

[15] Baba-zade V.M., Agaev S.A. Features of the structural conditions of localization and morphology of the ore deposit of the Filizchay deposit. // Bulletin of Baku University. Series of natural sciences, 1999, №1, p.91-108.

from -2 to +5) [13,16,17,18,19,20]. The location of δ S^{34} in authigenic sulfides of Lower-Middle Jurassic shales in the positive region indicates a limited limit to the fractionation of S^{32} and S34during SO_4^2 reduction. In accordance with the genetic model proposed by N. M. Strakhov (1960) for the widespread type of authigenic sulfide in pyrite-siderite nodules, the enrichment of pyrite with sulfur in heavy isotopes does not contradict the model of nodule formation. The limit of fluctuations in the sulfur isotopic composition of massive (pure) ores of two large pyrite deposits of the Greater Caucasus (Filizchay and Gyzyl-Dera deposits) is the same as in the pyrite deposits of the Devonian volcanic basalt formation of the Urals and the North Caucasus. This, in turn, indicates that these deposits are genetically related to large endogenous sources of sulfide sulfur mineralization. In small hydrothermal-metasomatic and hydrothermal -sedimentary coal deposits, δ S^{34} is about +5‰. This limit approaches authigenic pyrites with an average δ S^{34} value of about +10‰[16]. The difference in S^{34} in sulfides from sulfides at large deposits and small occurrences can be explained by double contamination of the latter's sulfur sources. Sulfides of small occurrences contain two types of sulfur: 1) endogenous and 2) authigenic of primary sedimentary-diagenetic origin. It should also be noted that the limits of δ S^{34} fluctuations may be important for the predictive assessment of individual manifestations. Thus, the statistical limit of the most promising manifestations of δ S^{34} is +5‰.

4.4. Conditions for the formation of reservoir deposits of the Sarybash structural-formational zone. The geological-structural

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[16] Buadze V.I., Kaviladze M.I., Melashvili T.A. Sulfur isotopes and questions of the genesis of sulfide deposits at the Kizil-Dere deposit (Dagestan Autonomous Soviet Socialist Republic) // Geology of ore deposits, 1973, No. 3, p.. 52-65.
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[18] Zairi N.M. Isotope-geochemical models of the formation of deposits of the gold-carbon formation. Author's abstract. diss. ... doc.geol.-min. Sci.M.: 1992, 46 p.
[19] Smirnova V.I., Chernitsyn V.B., Ivanov G.I. and others. Pyrite deposits of the Greater Caucasus.M.: Nedra, 1973, 256p.
[20] Trufanov V.N. Thermobarogeochemical conditions for the formation of ore deposits in the Greater Caucasus: Author's abstract. diss. ... doc. geol.-min. Sci. Tbilisi,1983, 48 p.

position and material composition of the ores show that kolchedan-polymetallic and copper-pyrrhotite ores belong to the same type of mineralization, are controlled by deep cracks and are closely related to the underlying volcanic rocks. The genesis of the Kolchedan ores, classified by one group of researchers as hydrothermal-metasomatic, by others as sedimentary-metamorphogenic, and by the third group as polygenic, combined formations, has caused a very wide discussion in the last 20-30 years. This issue is especially discussed by V.I. Smirnov (1973)[21], G.A.Tvalchrelidze (1973)[22], N.M.Zairi (1972)[18], J.S.Mazanov (1969)[23], N.G.Kurbanov (1986)[9] etc. widely interpreted in his research. Pure pyrite masses in kolchedan-polymetallic deposits of Filizchai[21] type were formed by sedimentation, and above them there was a polymetallic sulphide mineralization with hydrothermal origin. As for copper-pyrrotin deposits, mineralization is more related to the metamorphism process. Side rocks and organic compounds scattered in them played an important role in the formation of these deposits.

They constantly create a hydrogen-methane environment in black-colored silty-clayey, partially metamorphosed rocks, which led to the formation of pyrrhotite and generally sulfide-containing ores[24].

Layered diabase and gabbro-diabase dikes do not play a significant role in the localization of ores. They are usually distant from their ore bodies and rarely contain sulfide inclusions and veinlets in the selvages. The mineralization process is divided into stages due to tectonic faults. In the first stage of mineralization, hydrothermal sediment,

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[21] Smirnov, V.I. The relationship between sedimentary and hydrothermal processes during the formation of sulfide ores in the Jurassic flyschoids of the Greater Caucasus // - Moscow: Rep. USSR Academy of Sciences,- 1967. v.177, №1, - p.179-181.

[22] Tvalchrelidze, G.A., Buadze, V.I. Geological features and conditions for the formation of pyrite-polymetallic deposits of shale eugeosynclines // Geosynclinal and magmatic formations and their ore content. Tr. IG and Geochemistry UC USSR Academy of Sciences, vol. 102. – Sverdlovsk: - 1973. - p. 25-44.

[23] Mazanov, D.D. Lithology and genesis of Jurassic deposits of the Greater Caucasus within Azerbaijan / D. Mazanov. – Baku: publishing house of the Academy of Sciences of Azerbaijan. SSR, - 1969. - 249 p.

[24] Osetrov O.A. Sulfide deposits of non-ferrous metals in shale strata. M.: Nedra, 1978, 207 p.

second hydrothermal metasomatic and third stage hydrothermal metamorphogenic ores were formed. The products of these stages are manifested in different fields of the region with different intensity. It is believed that the ores of the first stage [9] are paragenetically related to poorly differentiated basalt-andesite-dacite, the second - to sequentially differentiated basalt-andesite-dacite-rhyolite, and the third stage - to differentiated stage rocks. gabbro-diorite-plagiogranite formation. As can be seen, the pyrite deposits on the southern slope of the Greater Caucasus were formed as a result of a complex and long process of mineralization and belong to combined objects of the polygenic-polychronic

Convergence and polygenic mineralization is evident in the Jurassic Formation proposals of the Greater Caucasus[2]. type[1,10,15,22,25,26]. Biogenic-sedimentary, authigenic concretionary, exhalation-sedimentary, volcanic-hydrothermal-metasomatic, metagenic-lateral-secretionary models of mineralization have also been proposed[9,15,18,23,27,28]. It has been established that sulfides of the pyrite-base-metallic subformation (primary-layered, exhalation-sedimentary pyrite ores and late hydrothermal-metasomatic pyrite-base-metallic ores), formed at two successive stages of mineralization, are obviously replaced by sulfides

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[27] Smirnov, V.I. The relationship between sedimentary and hydrothermal processes during the formation of sulfide ores in the Jurassic flyschoids of the Greater Caucasus // - Moscow: Rep. USSR Academy of Sciences,- 1967. v.177, №1, - p.179-181.

[28] Bogush, I.A. Genetic information content of ores and minerals of deposits of pyrite formation: / Abstract of thesis. doc. geol.-min. Sci. / Tbilisi, 1985, - 36 p.

of the copper-pyrrhotite subsuite[29,30]. At the same time, cases of opening of pyrite-polymetallic ores with veins containing quartz-carbonate-pyrite-sphalerite-galena (hydrothermal-vein subformation) were observed.

All of these features are reflected in the sediments of the Sarybash structural-formational zone[31].

Copper-pyrrotin deposits are developed along longitudinal thrusts, complicating the domes of the wings of large linear anticlines and accompanied by rods of solid ores of the same composition.

Chapter V. Prospective assessment of the Sarybash structural-formational zone and patterns of placement of Kolched ore occurrences

5.1. Patterns of placement of pyrite-polymetallic and copper-pyrrhotite manifestations. Although there are quite obvious differences in the conditions of formation of pyrite-polymetallic and copper-pyrrhotite mineralization, there are a number of common patterns in the formation of these deposits. In general, an analysis of a sufficient amount of material devoted to carbon-ore provinces shows that the geological position of these deposits consists primarily of a spatial connection with the distribution of volcanic and volcanogenic-sedimentary rocks in folded provinces and deep faults. The belt-like arrangement of kolchedan-polymetallic deposits, the distribution of volcanic rocks in the areas of their development and other features determine the spatial and temporal relationship of mineralization with deep cracks. These faults have long controlled deep-seated basaltoid magmatism and associated hydrothermal liquefaction.

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[30] Baba-zadeh V.M. Pyrite metallogeny and evolution of Meso-Cenozoic volcanism // Bulletin of Baku University. Series of natural sciences,1999, №4, p.107-127.

[31] Ganbarova E.F. Main geological features and genesis of pyrite-polymetallic and copper-pyrrhotite mineralization in the Saribash structural-formational zone of mineralization on the southern slope of the Greater Caucasus // News of Baku University. Natural Sciences Series. Baku, 2021, № 3, p.84-92.

5.2. Conditions of localization of kolchedan-polymetallic and copper-pyrrotin mineralization. In order to determine the natural place and conditions for the localization of ore-bearing objects, we consider it necessary to focus on the following issues: 1) position of mineralization in stratigraphic cut of rocks; 2) connection of mineralization with folded and cleavage structures; 3) relationship of mineralization with magmatic rocks; 4) features of formation of ore-bearing zones. Lithological-stratigraphic control of kolchedan mineralization is one of the most important criteria for the detection of this type of ore both on the southern slope of the Greater Caucasus and on the Talachay-Kurmukchayar site. Tectonic movements played an important role in precipitation (transgressive or regressive series), volcanite distribution and concentration, and mineralization. Thus, longitudinal deep cracks determined the regional location of the structural zones. Mineralization is concentrated in the immediate vicinity of the old deep fault at the junction of the Tufan and Sarybash structural and formation zones. Cross-sectional structures also played a significant role in the localization of ores of the Kolchedan formation. They divided the studied area into transverse blocks. The industrially important mineralization is formed by flexural bends at the junctions of uplifted and downlifted blocks.This pattern is typical not only for the area under study, but also for the Balaken-Sheki metallogenic province as a whole. One of the important factors in the localization of Kolchedan mineralization is the presence of products of underwater basalt magmatism, in other words, magmatic factor. The presence of layered intrusions containing gabbro-diabase indicates that the flow of magmatic material was of a jet nature and used pre-existing crack channels. It isn`t coincidence that the main development zone of igneous rocks is located near the fractures. Probably, that conditions were created during this period to facilitate the recovery of mineralized hydrothermal solutions from the subsoil. Apparently, mineralization is paragenetically related to magmatic formations in space. The source of the Kolchedan mineralization was the post-volcanic ore release of the original spylite-diabase magmatism. During this magmatism, large quantities of sulfur and, possibly, masses of iron were brought into the sea basin.

Mineralogical (high concentration of syngenetic pyritization in mudstones, framboidal pyrite, pyrite nodules, siderite nodules, ocher, zones of derivative sulfide enrichment, with covellite), geochemical and geophysical anomalies of a complex type are also favorable signs for kolhedan-base metal mineralization.

CONCLUSION

1. The localization of the mineralization is determined by the tectonic structure: longitudinally oriented deep faults (Main Caucasian Range, Kohna-madan and Malkamud) occupy a dominant position and determine the paths of the products of magmatism and ore solutions. As a result, both magmatic and ore masses settled along the rifts, forming dyke belts and ore zones. The ore zone, located in the north, is characterized by the presence of numerous copper-pyrrotin deposits and manifestations limited to the Akhtichai and Main Caucasian faults (Gykhikh-Sagator, Gizildara, etc.). The second ore zone (Filizchay zone) is located between the Main Caucasian and the Malkamud zone. Polymetallic mineralization of hard coal (Filizchay, Karabchay, etc.) has formed in this zone. South of the Malkamud Fault is the Catekh-Gumbulchay Kolchedansko-polymetallic ore zone (Catekh, Cheder, Gumbulchay).

2. The southern slope of the Greater Caucasus is divided into blocks by transverse faults (Balakan-Zagatala, Gakh, Ismayilli). They are inversion uplifts and are characterized by a large thickness of ore-bearing deposits. The complexes of magmatic rocks and ore deposits are located especially on Balaken-Zagatala block. Thus, in tectonic terms, the regularities of deposit placement are determined by longitudinal fractures and block structure of the region.

3. The structural formation zones where deposits are located are represented mainly by terrigenous deposits. Ore accumulations are a common occurrence in areas that have a variety of age and composition. It was determined that, mineralization corresponds to three stratigraphic levels – pliensbachian, toarcian and aalenian.

4. Regional and local zoning is distinguished, which characterizes the regular spatial location of ore zones that localize different types of ore deposits.

5. It was determined that the source of colchedan mineralization was the postvolcanic ore-generating exhalation of the initial spilite-diabase magmatism. During this magmatism, large amounts of sulfur and probably iron mass were brought into the sea basin.

6. Generally, the stratigraphic levels of Pleinsbachian, Toarian, Aalenian and Lower Cretaceous are clearly defined in terms of the different age-groups of the Sarybash structural and formation zone. The most intensive mineralization occurred in Pleinsbachian, Toarian and Aalenian; these deposits can be considered promising;

Relatively high reserves of copper, polymetals, gold and silver in the Sarybash field of mineralization have been established, the prospects of the region for these elements are undeniable. Undoubtedly, these studies could lead to an increase in mineral resources of the southern slope of the Greater Caucasus. From this point of view, it is recommended that prospecting and exploration be carried out in the deep horizons of the zone;

The main point of the prognostic-metallogenic assessment of pyrite-polymetallic mineralization of the Jurassic complex is to determine the mutual age relationships of ore strata and ore masses of the largest deposits of the region (Filizchay, Kyzyl-Dare, Kateks, Kashdag, etc.) to do this.

The main provisions of the dissertation are published in the following works (articles and extended theses of conferences and seminars)

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