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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

COPPER-ARSENIC AND PYRITE-POLYMETALLIC OCCURRENCES OF GADABAY ORE REGION AND THEIR LOCATION PECULIARITIES

Specialties: 2520.01– Geology, prospecting and exploration of solid minerals, minerageny
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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the research topic. Gadabay ore region is one of the main mineral-raw material resources for the forming of the gold mining industry in the independent Republic of Azerbaijan. It was in this ore region that Azerbaijan International Mining Company (AIMC) began producing gold, silver and copper for the first time after the declaration of Azerbaijan's independence and stil continues to do. Although the fact that the ore region is well studied, a number of issues, especially the assessment of the perspective of the flanks and deep horizons of the Gadabay deposit, the study of other ore deposits and occurrences, which are abundant in the region, by modern geological and geochemical methods remain relevant.

The ore region belongs to the Jurassic-Cretaceous Lok-Karabakh island arc, which was formed as a result of the subduction of the Tethys metallogenic belt to the Eurasian edge of the Tethys Ocean in the Lesser Caucasus. According to the results of geological-exploration and scientific-research works carried out in the Gadabay ore region in recent years, belonging of the Gadabay deposit to the high-sulfidation type with Cu-Au-Ag mineralization and the Gadir and Umid deposits, which are located near it, to the low sulfidation type with Au-Ag-Zn-Pb mineralization gives hope for the discovery of new perspective large porphyry-epithermal ore deposits as part of a single epithermal system of the ore region. The location of gold-copper-porphyry ores in the Gadabay deposit and its calling by experts as the "Gadabay-type copper deposit" of the Lesser Caucasus can be a reliable criterion for similar and complex deposits of noble, non-ferrous and rare metals in the ore region.

The purpose of the work is to determine the regularities of the location of deposits and occurrences of the Gadabay ore region by modern complex geological research methods and to prepare forecasting and search criteria to discover new prospective areas.

The main issues of the research:

- study of petrological peculiarities of magmatic complexes of the Gadabay ore region;

- accurate study of deposits and occurrences distributed in the ore region and compilation of lithological-structural maps;
- study of mineral associations of ore region and texture-structure of ores;
- study of the peculiarities of hydrothermally altered wall rocks;
- determination of ore-magmatic zonation;
- study of the behavior of components in the process of formation of different types of derived quartzites;
- study of geochemical peculiarities of ores and metasomatites; compilation of geochemical anomaly maps;
- determination of crystallization temperature and formation conditions of ores of the Gadabay deposit;
- creation of a generalized model of deposits of the Gadabay epithermal system.

Actual materials and research methods. The dissertation is based on the materials collected by the author during his doctoral studies (postgraduate education) and later during the geological research works, which serve to establish geological prospecting works in order to identify the most prospective areas in the Gadabay ore field, in the Azerbaijan International Mining Company (AIMC), in which he currently works.

Fund materials, published literature, as well as maps based on the information of the company where the author works, the results of chemical, mineralogical, geochemical analyzes were used during the dissertation work. Analysis of macro- and microelements in rocks was carried out by method of X-ray fluorescence (XRF) at laboratory of SGS Mineral Services UK LTD in Ontario, Canada. Descriptions of 120 thin sections, 30 X-ray fluorescents, more than 500 microelements, including Au, Ag, Cu, 20 isotopes and the results of liquid-gas input analysis were used during the research work.

Scientific innovations: 1) According to the study of the petro-geochemical peculiarities of Bajocian volcanic rocks, it was determined that while Lower Bajocian volcanic rocks were accompanied with low-temperature fluids, Upper Bajocian volcanites were contaminated with molten silicate alloys due to subducted

rocks; 2) It was determined that the Gadabay deposit belongs to the high sulfidation type with Cu-Au-Ag mineralization, the Gadir deposit and the Umid zone belong to the low sulfidation type with Au-Ag-Zn-Pb mineralization; 3) Deposit and occurrences distributed in the Gadabay ore region were systematized and their lithological-structural maps were compiled; 4) 4 main mineral complexes have been divided in the Gadabay ore region: 1. quartz-adular-pyrite; 2. predominant chalcopyrite-sphalerite; 3. late copper mineralization stage - chalcosine- covelline; 4. galena-tennantite mineralization; 5) Using space satellite data, prospective areas of mineralization characterized by hydrothermal-metasomatic changes represented by alunitization, kaolinization, sericitization, silicification, pyrophillitization within the Gadabay ore region were identified; 6) Mineralization has been formed over a wide period of time in the ore region. A number of deposits (Bittibulag) were formed due to the formation of andesite and andesibasalt complexes in the early Bajocian and late subvolcanic formations (Ertepe) in the Bathonian. Most deposits (Gadabay) were formed in late Bajocian when subvolcanic acid rhyolites formed; 7) Crystallization temperature, physic-chemical formation conditions, source of hydrotherms of ores of the Gadabay deposit were determined; 8) Most deposits and occurrences of the Gadabay epithermal system are associated with the Gadabay-Bittibulag deep fault and are suitable for mineralization and it has been determined that horst-type zones are more promising for mineralization in the region; 9) A generalized model of most deposits of epithermal system of the Gadabay ore region has been created.

Defended provisions:

1. The main structural peculiarities and location regulations of ore deposits and occurrences of the Gadabay ore region.

2. Separation of the Gadabay epithermal system, conditions of physico-chemical formation, generalized model.

Practical significance of the work. According to the complex research, the factors revealed for the formation of deposits and occurrences in the Gadabay ore region allow to predict new

promising areas and identify new levels of localization of ores. Ore metasomatic changes, which were detected by various methods, are located along the ore-controlling structures and allow to reveal specific structures that are promising for mineralization. These metasomatites may be promising search criteria for the discovery of hidden ore deposits in the Gadabay ore field. A map of hydrothermally altered metasomatites and mineralization zones for the north-west of the ore region may allow the discovery of new ore deposits. The detected zoning of hydrothermal metasomatic altered rocks allows to determine the erosion section of industrially important mineralization and predict it in deep horizons. The determination of the "Gadabay epithermal system" and the creation of a geological-genetic model give grounds for the discovery of analogic deposits and occurrences in other structural formation zones of the Lesser Caucasus.

Approbation and publications of the work. The main results of the dissertation were presented at the international conference "New results of regional geology, geodynamics, metallogeny of the Lesser Caucasus" (Tbilisi, 2013), at the international conference dedicated "Tectonics and metallogeny of Tethys" (Cheshme, Turkey, 2016), at the Republican Scientific Conferences (Baku, 2015, 2019, 2021). 16 articles (2 articles in journals included in the **Web of Science database of Clarivate Analytics**), 5 theses have been published in republican and foreign journals and collections on the topic of the dissertation and reflect the main scientific results of the dissertation.

Work content and structure. The dissertation consists of an introduction, 6 chapters, conclusion and recommendations, a list of 132 references. The total size of the work consists of 195 pages (203171 characters), including 78 figures and 22 tables.

The author expresses his deep gratitude to the supervisor academician Vasif Babazade, to Mr. Reza Vaziri, President of Azerbaijan International Mining Company, all employees of the Company, including chief geologists Farhang Hejazi and Hasan Chalabi, the company's manager of exploration geology, PhD in Earth Sciences

Anar Valiyev, the manager of mining geology, PhD in Earth Sciences Rashad Asgerov, geologists – Shakir Gadimov, Aydin Bayramov, Sabuhi Mammadov, Mehman Talibov, Javid Ibrahimov, Zaur Jafarov, Rashad Aliyev, as well as the professor-teacher staff of the Faculty of Geology for the opportunity and assistance in the implementation of the dissertation. The author deeply remembers his teacher Professor Vagif Ramazanov and former head of the company's geological department Akir Isayev, chief geologist Hasan Chalabi, who passed away prematurely, with his deep respect for their valuable advice, comments and assistance in conducting field research while working on the dissertation.

CHAPTER I. GEODYNAMIC-GEOLOGICAL PECULIARITY OF THE GADABAY ORE REGION

1.1. Geodynamic position of the Lesser Caucasus. The Tethys orogenic belt was formed as the result of the convergence of African-Arabian and Eurasian plates, as well as a number of small plates (Adamia et al.[1], 2011; Rolland et al., 2012[2]). As a continuation of this, collisions of different plates occurred by colliding magmatism and ore deposits (Rustamov, 2005[3]; Koronovsky N.V., Demina L.I., 2007[4]; Dilek et al., 2010[5]; Ricards, 2015[6]; Imamverdiyev et al., 2017[7]). The Lesser Caucasus is a major part of the Tethys Belt, which stretches from the Black Sea to the Caspian Sea passing through Georgia, Armenia and Azerbaijan. This ribbon-shaped line, which extends to Asia, connects the Western and Central metallogenic belts of Tethys (Jankovic, 1977[8], 1997[9]; Richards, 2015[6]). The Lesser Caucasus consists of the Lok-Karabagh, Goycha-Hakari and Miskhan-Zangazur structural-formation zones covering the edges of the Eurasian plate in the north and Iran plate in the south [Geology of Azerbaijan, vol.3. Magmatism, 2001[10]; Geology of Azerbaijan, vol.4.Tectonics, 2005[11]]. The part of the edge of the Eurasian plate that falls to the Lesser Caucasus is known as the Transcaucasian (Lesser Caucasus) microcontinent (Rustamov, 2005[3]; Adamia et al., 2011[1]) and consists of the Lok-Karabakh zone, which stretches for up to 350 km. This zone is described as an island arc characterized by calcium-alkaline magmatism as a result of the subduction of Neothetiys from the Jurassic period to the Cretaceous and is divided into different segments by transverse faults characterized by strong volcanism in the Bajocian-Bathonian and Kimmeridgian. Neoproterozoic-Paleozoic bedrock rocks with metamorphic and granite structure were covered with Jurassic volcanic-sedimentary rocks and appeared in Lok, Khram, Dzirul,

[1]*Adamia, Sh. Geology of the Caucasus: a review / Sh.Adamia, G.Zakariadze, T. Chkhotua [et al.] // Turkish Journal of Earth Sciences, - 2011. v.20, - p. 489-544*

[2]*Rolland, Y. Caucasus collisional history : Review of data from East Anatolia to West Iran // Condwana Research, - 2017. v.49, - p. 130-146*

[3]*Rustamov, M.I. South Caspian basin - geodynamic events and processes / M.I. Rustamov, - Baku: Nafta-Press, - 2005. - 245 p. (in Russian)*

[4]*Koronovsky, N.V., Demina, L.I. Collisional stage of the development of the Caucasian sector of the Alpine fold belt: geodynamics and magmatism // - Moscow: Geotectonics, - 1999. No. 2, - pp.17-35.(in Russian)*

[5]*Dilek, Y., Imamverdiyev, N., and Altunkaynak, S. Geochemistry and tectonics of Cenozoic volcanism in the Lesser Caucasus (Azerbaijan) and the peri-Arabian region: Collision-induced mantle dynamics and its magmatic fingerprint // International Geology Review, - 2010. v.52, - p. 536-578.*

[6]*Richards, J.P.Tectonic, magmatic, and metallogenic evolution of the Tethyanorogen: From subduction to collision // Ore Geology Reviews, - 2015. v.70, - p. 323-345.*

[7]*Imamverdiyev, N.A. Petrology and geochemistry of the late Cenozoic collision volcanism of the Lesser Caucasus. / N.A. Imamverdiyev, A.A. Valiyev, M.Y. Hasanguliyeva - Baku: Laman Publishing Polygraphy LLC publishing house, - 2017. - 317 p. (in Azerbaijani)*

[8]*Jankovic, S. The copper deposits and geotectonic setting of the Tethyan Eurasian metallogenic belt // MineraliumDeposita, - 1977. v.12, - p. 37-47.*

[9]*Jankovic S. The Carpatho-Balkanides and adjacent area: a sector of the TethyanEurasian metallogenic belt // MineraliumDeposita, - 1997. v.32, - p. 426-433.*

[10]*Geology of Azerbaijan: [in 10 volumes]. / Ed. Academician A.A.Alizadeh. - Baku: Nafta-Press, - v. 3, Magmatism - 2001. - 434 p. (in Azerbaijani)*

[11]*Geology of Azerbaijan: [in 10 volumes]. / Ed. Academician A.A. Alizade. - Baku: Nafta-Press, - vol. 4, Tectonics - 2005. - 505 p. (in Azerbaijani)*

Asrikchai massifs of Lok-Karabakh zone (Ismail-Zade, 1999[12]; Geology of Azerbaijan, vol.3, Magmatism, 2001[10]; Shengelia et al., 2006[13]).

1.2. Geological structure of the Gadabay ore region. The Gadabay ore region is located in the Shamkir uplift of the Lok-Karabakh structural-formation zone of the Lesser Caucasian megaanticlinorium. The region has a complex geological structure and is composed of Middle and Upper Jurassic volcanogenic, volcanogenic-sedimentary rocks complicated by intrusive masses and fault structures of different ages and different compositions.

The most widespread rocks in the region are Middle Jurassic. A limited amount of Upper Jurassic rocks are also noted. The most common of the Middle Jurassic rocks are rocks of the Bajocian stage and they are divided into two substages – the Lower and Upper Bajocian substages, which differ in composition. Bajocian sediments lie unconformably on the sandstone-clay rocks of the Lower Aalenian and are covered conformably and sometimes unconformably with the rocks of the Bathonian stage. If rocks of Bathonian stage are absence, Bajocian sediments are unconformably covered by various Upper Jurassic strata (Abdullaev et al., 1988[14]). Bajocian aged volcanogenic formations form contrast andesibasalt-rhyolite formations and are divided into Lower Bajocian aged andesibasalt and Upper Bajocian aged dacite-ryolite complexes (Abdullaev et al., 1988[14]). It was determined that most of the known ore deposits and occurrences in the Gadabay ore region are located mainly at the intersections of

[12] *Ismail-zade, A.D. Geodynamic settings of the Alpine magmatism of the Caucasus // Materials of the International Conference "Geodynamics of the Black Sea-Caspian Segment of the Alpine Fold Belt and Perspectives for Prospecting for Mineral Resources", - Baku: - 1999, - pp. 145-146. (in Russian)*

[13] *Shengelia, D.M., Tsutsunava, T.N., Shubitidze, L.G. New data on structure, composition, and regional metamorphism of the Tsakhkunyats and Akhum-Asrikchai massifs, the Lesser Caucasus // Doklady Earth Sciences, - 2006. v.409A, - p. 900-904.*

[14] *Mesozoic magmatic formations of the Lesser Caucasus and endogenous mineralization associated with them / R.N. Abdullaev [et al.]. - Baku: Elm, - 1988.- 158 p.(in Russian)*

circular structures reflecting volcanic-plutonic massifs with linear fault zones. All intrusive, subvolcanic and other magmatic masses formed along deep faults.

Investigations conducted within the Gadabay ore region have shown that the metallogeny and magmatism of the Shamkir uplift are closely related to Gadabay-Bittibulag, Galacha-Chardakhli, Barum-Samanlig, Yasamal (Lesser Caucasus front) deep faults.

Summarizing the published periodic literature, it was concluded that the Lesser Caucasus was formed as a result of the concussion and collision of the Eurasian and African-Arabian plates and evolved from the Jurassic aged island arc to the Neogene-Quaternary collision. As a result of this geodynamic evolution, various ore deposits related to specific tectonic and magmatic processes have been formed. These deposits are genetically related to deposits and occurrences in the metallogenic provinces of Eastern Turkey and Iran. It should be noted that if the deposits and occurrences of Tethys in the Eastern Turkey and Iran segments are considered with sufficient accuracy(Yigit, 2009[15]; Chiaradia, M., 2014[16]; Aghazadeh et al., 2015[17]), the information on its deposits in the Lesser Caucasus segment is incomplete (Tvalchrelidze, 1961[18], 1980[19]; Kekelia et al., 2008[20], Baba-zade et al., 2012[21], 2015[22], 2020[23]).

[15] *Yigit, O. Mineral deposits of Turkey in relation to Tethyanmetallogeny: Implications for future mineral exploration // Economic Geology, - 2009. v.104, - p. 19-51.*

[16] *Chiaradia, M. Copper enrichment in arc magmas controlled by overriding plate thickness // Nature Geoscience, - 2014. v.7, - p. 43-46.*

[17] *Aghazadeh, M. Temporal-spatial distribution and tectonic setting of porphyry copper deposits in Iran: Constraints from zircon U-Pb and molybdenite Re-Os geochronology / M.Aghazadeh, Z.Hou, Z.Badrzadeh [et al.] // Ore Geology Reviews, - 2015. v.70, - p. 385-406.*

[18] *Твалчрелидзе, Г.А. Эндогенныеметаллогении Грузии / Г.А. Твалчрелидзе. - Москва: Госгеотехиздат, - 1961. – 343 с. Tvalchrelidze, G.A. Endogenous metallogeny of Georgia / G.A. Tvalchrelidze. - Moscow: Gosgeotekhizdat, - 1961. - - 343 p. (in Russian)*

[19] *Tvalchrelidze, G.A. Copper metallogeny of the Caucasus / inJankovic S., Sillitoe R.H., eds, European copper deposits: Society for Geology Applied to Mineral*

The author tried to fill this gap to some extent in the dissertation.

CHAPTER II. PETROLOGY OF MAGMATIC COMPLEXES OF THE GADABAY ORE REGION

As the Gadabay ore region and generally, the Shamkir uplift are very complex for their tectonic structure, its magmatism is also very complex. Magmatic processes have developed in several stages in the conditions of the island arc in this region.

Many researchers have been studying the magmatism of the Gadabay ore region. Among them R.N.Abdullayev, V.M.Baba-zadeh, A.C.Ismayilzadeh, H.H.Kerimov, M.N.Mammadov, H.V.Mustafayev, M.A.Mustafayev, V.G.Ramazanov, M.I.Rustamov and many other scientists can be mentioned. The results of the research carried out by these scientists are widely described in monographs, in the magmatism part of the multi-volume Geology of Azerbaijan. Almost all of these scientists mentioned three stages of magmatism in the Gadabay ore region: Bajocian, Bathonian and Upper Jurassic.

The magmatism of the region, the facial peculiarities of magmatic rocks and their petrographic peculiarities are given with

Deposits, International Symposium, Bor, Yugoslavia 18-22 September 1979, Proceedings, - 1980. - p. 191-196.

[20]*Kekelia, S.A. Gold deposits and occurrences of the Greater Caucasus, Georgia Republic: Their genesis and prospecting criteria / S.A.Kekelia, M.A.Kekelia, S.I.Kuloshvili [et al.] // Ore Geology Reviews, -2008. v.34, - p. 369-389.*

[21]*Baba-zadeh, V.M. Noble metal ore-magmatic systems / V.M. Baba-zadeh, Sh.F.Abdullaeva. - Baku: publishing house of "Baku University", - 2012. - 276 p. (in Russian)*

[22] *Baba-zadeh, V.M. Gold-bearing sulfide deposits of island arc paleosystems, their metallogenic peculiarities and conditions of geodynamic development / V.M. Baba-zadeh, SA Kekelia, Sh.F. Abdullaeva [and others]. - Baku: SVS, 2015. -- 400 p. (in Russian)*

[23]*Baba-zadeh, V.M. The main features of the metallogeny of the Caucasus / V.M. Baba-zadeh, S.A.Kekelia, Sh.F. Abdullaeva [and others]. - M.: Publishing House Nedra LLC, -2020. - 187s. (in Russian)*

sufficient accuracy in the dissertation work. Then, the petrogeochemical peculiarities of Bajocian volcanites, which played an exceptional role in the location of ore deposits and occurrences widespread in the region, were analyzed. The rocks of bimodal-contrast basalt-rhyolite formation separated by R.N.Abdullayev, M.A.Mustafayev and others (1988)[14] during the Bajocian period were analyzed by various diagrams and it was found that the formation is dominated by basic (basalt and andesibasalt) and acidic (dacite, rhyolite) rocks, which, according to the sum of alkaline, belong to the normal alkaline-low potassium series, and some to the calcium-alkaline series. In other words, the Lower Bajocian volcanism, which belonged to the tholeiite series during the Middle Jurassic period, was replaced by the Upper Bajocian calcium alkaline series.

Bajocian volcanic rocks are close to the volcanites formed in the island arcs for their geochemical peculiarities. So, these rocks are poor in Nb, Ti, P and rich in Rb, Ba, Pb, U, Th. According to the amount of Rb, Nb, Y, the figurative points of Bajocian age volcanites are located in the area of island arcs. It was concluded that while Lower Bajocian volcanic rocks were accompanied with low-temperature fluids, Upper Bajocian volcanites were contaminated with molten silicate alloys due to subducted rocks.

CHAPTER III. BRIEF GEOLOGICAL PECULIARITIES OF DEPOSITS OF THE GADABAY ORE REGION

The Gadabay ore region is of great industrial and theoretical interest for its scale, variety of deposits and value. The lithological composition of the wall rocks and the long-term and complete process of magma differentiation have created favorable conditions for the formation of large amount of ore concentrations. In this case, the magma, which causes the rise of subvolcanic riodacites, created conditions for the formation of paragenetic associations of ore-forming minerals, which are widespread within the ore field and formed different composition and genetic types of deposits. First of all, this includes sulfur-copper pyrite ores, as well as separate concentrations of elements such as zinc, arsenic, lead, etc. The

following is a description of some of the deposits and occurrences (figure) formed in ore region.

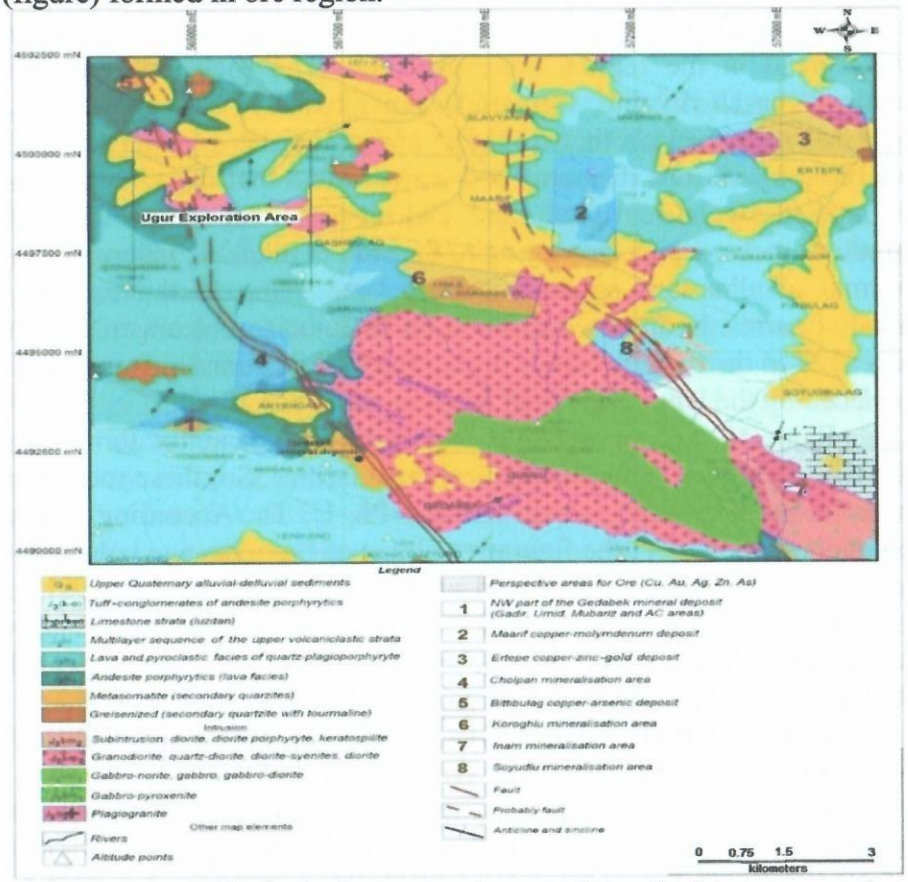

Figure. Lithological-structural map of the Gadabay ore region, showing perspective areas of *Cu, Au, Ag, Zn, As* elements (compiled based on materials of Azerbaijan International Mining Company)

Gadabay copper-pyrite deposit. The deposit is located in the borders of the north-eastern segment of the large Shamkir uplift. The ore area consists mainly of the Atabay-Slavyanka plagiogranite massif, which broke Bajocian aged volcanogenic formations, and the Late Jurassic Gadabay, Barum-Barsum, Gabakhtapa intrusions, which bordered it in a semicircle. All these intrusions are located

between Jurassic volcanogenic formations and split the Bajocian, Bathonian, Calloway-Oxford stages and have a contact effect on them. The shown magmatic formations are located in the zone of development of Gadabay-Dalidagh lineament in the north-west direction.

Bitti-Bulag copper-arsenic deposit. The formation of the deposit is a multi-stage process of hydrothermal ore formation. This is evidenced by the localization nature of endogenous mineralization, mineral composition of ores, wallrock changes of rocks. The intermittency of ore-bearing hydrotherms has led to vertical zoning, which is characterized by the substitution of pyrite, chalcopyrite-sphalerite-pyrite, pyrite-enargite and enargite-pyrite-barite type of ore from bottom to top. This change happened in a narrow range of temperature and is confirmed by the decrepitation of pyrite (320°) and enargite (240°), which are the main minerals of ores.

Ertepe deposit of copper-zinc ore. The zone extends over a distance of 900m and has been tested in 7 surface mountain excavations with 100-250m between them. The amount of copper is 0,11-0,86% in all sections. 0,1 g/t Au, Co up to 0,07% was determined in some sections.

Fault and dyke zones, which play an important role in the localization of mineralization, have the opposite bedding in the same elongation and this may indicate that the ore mass compressed between the dyke strip and the fault zones is stock-shaped at depth.

The conditioning of the abovementioned elements in copper-zinc ores, as well as the localization of useful components in the form of stock provide the basis for the investigation and exploration of the deposit again.

Occurrences of Shekerbey polymetallic ores. The Shekerbay area is of some interest for its copper and lead-zinc mineralization. As a result of complex geophysical and geochemical works carried out in the field, intensive aureole of copper and lead belonging to the fault zone is observed and shows the perspective of the central part to these elements. In addition, veins and impregnation of hematite are observed in andesites (area of 0, 5 sq. km) in the fault zone at the

eastern flank of the Central part. Copper greeny is also noticed here. The amount of copper in the bedrock varies from 0,02 to 0,45%. Traces of gold are observed in some rocks.

Gadir mineralization area. Veinlet-impregnation stockwork and vein-type of mineralization are developed in the field of mineralization, and stockwork mineralization-type is predominant. Intensive mineralization is observed in the central part of the stockwork and as it moves away from the center, the amount of gold and copper decreases. The thickness of the ore zone increases with the formation of quartz-sericite facies of derivative quartzites in the areas of intensive changing and hydrothermal alteration. Vein-type mineralization takes a dependent position in the zone and is also found in derivative quartzites; where the mineralization consists of quartz veins saturated with sulfides. The above mentioned are very similar to the geological and structural peculiarities of the known gold-copper pyrite and copper-porphyry deposits of Gadabay ore-magmatic system in terms of morphology and the internal structure of the mineralization (Baba-zadeh, et al., 2015[24]; Veliyev et al., 2018[25]).

A number of deposits and zones have been identified in **Ughur area**: they are located in border of Rza gold (Au-Ag) deposit *(named in honor of Mr. Reza Vaziri, President of the AIMC)* with high sulfidation, Giziljadagh zone with high sulfidic sulphur mineralization (Au-Ag-S), Shah Yatag mineralization zone (Au-Ag-Cu) with high sulfidation, Yukhari Narzan mineralization zone (Au-Ag) with high sulfidation and Gadabay-Bittibulag deep fault. The geological structure of the mineralization region includes Upper Bajocian rhyolite-dacites and their agglomerate tuffs, derivative

[24]*Baba-zadeh, V.M. New perspective Gadir mineralization field in Gedabey ore region / V.M.Baba-zadeh, A.A.Veliyev, Sh.F., Abdullayeva [et al.] // Reports of National Academy of Sciences of Azerbaijan, - 2015. no.2, - p.74-79.*

[25]*Veliyev, Anar Geological Setting and Ore Perspective of the New Discovered Gadir Low Sulfidation Epithermal Deposit, Gadabay NW Flank, Lesser Caucasus, Azerbaijan / AnarVeliyev, Aydin Bayramov, Javid Ibrahimov [et al.] // Universal Journal of Geoscience, - 2018. 6(3), - p.78-101.*

quartzites with complex genesis. Besides these rocks, fumarale-solfatara type and contact hydrothermalites formed due to the acid volcanism of the Upper Bajocian are also observed. Intensive barite and barite-hematite veins and veinlets are observed on the surface in the area. Samples from three trenches at a distance of 270m in mineralization zones were analyzed and positive results were obtained in accordance with gold and silver. 0,3-2,0 g/t Au, 1,0-15,0 g/t Ag were detected in the analyzed samples and the presence of high-quality gold mineralization was indicated on the surface. Hurricane indication of Au, Ag, Cu were indicated at deeper depths (Au - 10,27-18,45 g/t, Ag - 46,21-74,53 g/t, Cu - 0,01-0,08%).

Umid zone. The zone is located 0,6km west of Gadir zone. The zone is located between two fault and looks like a horst. It consists of a lava fascia of rhyolite-dacite porphyries of the Upper Bajocian from a geological point of view. The volcanic-cluster rocks of the Bathonian stage, which consist of tuff breccias and tuff conglomerates containing andesite-porphyrite, are located above this fascia.

Maarif copper-molybdenum ore area. The ore area consists of andesite and diabase (metadolerite) porphyrites, quartz-plagiogranites and their tuffs of Bajocian-Bathonian stage. These rocks are fractured by quartz diorite, granodiorite-porphyry and plagiogranite intrusions, as well as subvolcanic masses of diabase variolite-dacite porphyries and are intersected by a dense network of faults near north-west, north-east meridional and width. The rocks have changed strongly (silicified, sericitized, pyritized in everywhere, chloritized in some places, etc.) in the ore area and often become derivative quartzites. Gold-copper-porphyry stockwork and gold-sulphide-quartz veins of ore bodies and mineralized masses are separated.

Cholpan mineralization area. If not considering the small number of derivative quartzites, the geological structure of Cholpan area is the same as the Gadabay deposit. The geological structure of the mineralization area includes volcanogenic-sedimentary formations of the Lower Bajocian stage, consisting of tuff

conglomerate, tuff sandstone andesite. The mineralization area is accompanied by ore-bearing Gadabay-Bittibulag faults and thick (up to 100-130 m) fault in the north-eastern direction at a vertical angle of 600. The mineralization zone passes through Garadagh to southwest from Cholpan. The rocks were loosened, brecciated, kaolinized, silicified and limonitized in the fault zone.

Koroghlu mineralization area. The area is located near Garadagh village, 1-1,5km north of Arigdam village. The surrounding rocks consist of a lava facies of rhyolite-dacite porphyries of the Upper Bajocian stage. The mineralization zone belongs to the north-western Dashkasan-Gadabay regional fault, which is of great importance in terms of magmatism and ore-bearing. The mineralogical composition consists of quartz, muscovite and sericite and small amount of biotite, andalusite, orthoclase, fluorite, chlorite, calcite, chalcedony and others.

Mineralization with a thickness of 0,1-3,0m on the surface is limited to derivative quartzites extending to a distance of 0,2-1,2 km. The amount of copper in the samples is 0,20-1,28%, molybdenum 0,01-0,2%, gold 0,20-2,36 g/t, silver 0,2-28 g/t, lead and zinc respectively 11 -5840 g/t and 65-14847 g/t.

The Soyudlu mineralization zone is located 2,0km south of the Soyudlu village (the junction of the Missu and Parakandsu rivers) and belongs to the central part of Gadabay gabbroid intrusion (figure 3.19). The zone is represented by three quartz veins impregnated with pyrite and chalcopyrite. The thickness of the veins varies from 0,15 to 1,0m. The variable range of copper amount is 0,01-1,1%, as well as lead 0,01-1,6%, zinc 0,02-0,27% and cobalt 0,02-0,16%.

CHAPTER IV. MINERAL ASSOCIATIONS OF THE GADABAY ORE REGION, TEXTURE-STRUCTURE OF ORES, PECULIARITIES OF WALLROCK ALTERATION

4.1. Mineral associations of the Gadabay ore region and texture-structure of ores. According to researchers of the Gadabay ore region and our observations, the ore region is divided into three main paragenetic mineral associations: the earliest – chalcopyrite – pyrite-chalcopyrite-sphalerite, pale ore-bearing and baritic chalcopyrite-sphalerite, barite-sphalerite and quartz, carbonates, barite, coarse-grained pyrite, chalcopyrite and pale ore formed as a result of recrystallization of late-early mineral associations.

Ores are divided into two main types: early sulfur pyrites and derivative copper-zinc (chalcopyrite-sphalerite with barite). These two industrial types of ores are formed in complex geological conditions, separated by time, but adapted to space (Kerimov, 1961, 1963[26]). Mutual junction of minerals is observed in them. The dissertation provides a detailed description of the most common minerals, chemical analysis, the sequence of minerogenesis of ores. According to the latest information, the Gadabay ore region is divided into 4 main mineral complexes: 1) quartz-adular-pyrite; 2) predominant chalcopyrite-sphalerite; 3) late copper mineralization stage - chalcosine- covelline; 4) galena- tennantite (Mursalov, 2018[27]). These types of mineralization have been more accurately identified in the central part of the Gadabay deposit (Valiyev et al., 2013[28]).

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[26] *Kerimov, G.I. Petrology and mineralization of the Gadabay ore cluster (Lesser Caucasus): [in 2 volumes] / G.I. Kerimov. - Baku: AN Azerb. SSR, - v. 1. - 1961 .-- 154 p. vol. 2. - 1963. -- 223 p. (in Russian)*

[27] *Mursalov S.S. Peculiarities of mineral associations and hydrothermal alteration of rocks of Umid zone (Gadabay ore region) // News of Baku University, series of natural sciences, 2018, No.4, p.61-69. (in Azerbaijani)*

[28] *Valiyev, A., Bayramov, A., Mursalov, S. Geology, resource, and future ore perspective of the Gadabay gold deposit, Azerbaijan // Conference on Recent Research Activities and New Results about the Regional Geology, the Geodynamics and the Metallogeny of the Lesser Caucasus. Tbilisi, Georgia, - 2013. - p. 23.*

Ores of Gadabay region are characterized by massive (homogeneous), crystalline-grained, sandy (soft-grained), druse, cement, breccia, breccia-shaped, vein, striped, loop-like, spotty-impregnation and impregnation textures. All divided textures are typical of early hypogenic ores and characterize sulphur pyrites and copper-zinc ores. The following structural types are distinguished in ores of the ore region: 1) sedimentary structure (hypidiomorphic, panidiomorphic, allotriomorphic, porphyric granular, interstitial, poikilit and myrmekite); 2) replacement structure (loop-like, eolation, intersection, skeletal replacement, reticular); 3) crushing structure (breccia, cement, porphyroclast); 4) fault structure of solid solutions (reticular, emulsion, subgraphic).

4.2. Peculiarities of wallrock alteration of the Gadabay ore region. V.I.Aliyev (1977[29]) identified two genetic types among the derivative quartzites in the Gadabay ore region: 1) fumarole-solfatara type of derivative quartzites, 2) contact (greisen) type of derivative quartzites. Kaolinite, alunite, pyrophyllite, dickite, kalloysite, montmorillonite, iron hydroxides, besides regenerated quartz are present in fumorale-solfatara type of derived quartzites and they form two or more balanced mineral associations, which are typical of derivative quartzites formed near the surface and replace propylitized rocks. Contact-greisen type of derivative quartzites were formed under the influence of gashydrotherms on rhyolite-dacite rocks after the rise of Gadabay intrusion and small stock-like porphyry intrusions (Jayirchai, Kharkhar, Garadagh, etc.). The main minerals that form this type of derivative quartzites are sericite, chlorite, calcite, barite, andalusite, muscovite, tourmaline, biotite, sillimanite, actinolite, fluorite, pyrite, iron hydroxides, etc. besides the predominant quartz. Copper-zinc-pyrite, copper-polymetal, copper-arsenic, copper-porphyry, etc. deposits in the Gadabay ore region are associated spatially and genetically with this type of derivative quartzites.

[29] *Aliev, V.I. Pyrite ore formation of the Lesser Caucasus: / abstract dis. doct. geol.-min. sciences. / Baku, 1976. -- 55p. (in Russian)*

The behavior of the components was estimated on the basis of their chemical analysis for different mineral facies in both genetic types of the metasomatic column in the Gadabay ore region.

As a result of estimation, the following sequence of component mobility was determined in fumarole-solfatara type of derivative quartzites: Mn Si Al K Na Mg Fe^{3+} Fe^{2+} H P Ti. The mobility order of the components was determined as Si Al Mg Ca Fe^{3+} Na K H Mn Ti Fe^{2+} in metasomatic facies of greisen type derivative quartzites (Mursalov, 2012[30]).

The evidence described above shows that according to the regularity in Gadabay deposit, ore-metasomatic zoning was manifested in the filtration metasomatizes established by D.S.Korzhinsky (1955[31]).

As a result of the exploration work carried out in the ore region, a number of wallrock hydrothermal alteration zones of great interest from the point of view of ore-bearing have been identified and consist of 5 main types: 1. propylitization; 2. argillization; 3. phyllitization; 4. potassium alteration and 5. silicification. Oxidation and carbonation are also observed in the Umid zone (Mursalov, 2018[27]). (Baba-zadeh et al., 2019[32]).

CHAPTER V. GEOCHEMICAL PECULIARITIES OF ORE AND METASOMATITE

Gold is found in the free state, as well as in the impregnation and dispersed state due to sulfides in ores of the ore region. Gold

[30] *Mursalov S.S. Hydrothermal alteration of wallrock in Gadabay ore field // News of Baku University, series of natural sciences, 2012, No. 1, p.151-164(in Azerbaijani)*

[31] *Korzhinsky, D.S. Essay on metasomatic processes // Main problems in the study of magmatogenic ore deposits. - Moscow: AS of the USSR (second edition), - 1955 .-- p. 335-456.(in Russian)*

[32] *Baba-zadeh, V.M. Determination of hydrothermal alteration and mineralization zones using ASTER data (Gadabay ore district) / V.M.Baba-zadeh, N.A. Imamverdiyev, M.I. Mansurov [etc.] // Baku University news, natural sciences series, - Baku: - 2019 . No.1, - p.69-78. (in Azerbaijani)*

participates in all paragenetic associations of many minerals. Special minerals of gold and silver - free gold and silver - are present in the pyrite ores of the Gadabay deposit and are associated with all major ore and vein minerals. However, most of the gold is finely dispersed in the ores. The amount of silver in ores is quite high in comparison with gold, but the amount in the form of a special mineral is much lower than gold. The main mass of finely dispersed gold is associated with early pyrite, but free gold with late – pyrite-chalcopyrite-sphalerite association. In other words, the distribution of gold in the ore depends mainly on its type and location. Its high amount is observed in the dependent side of the sulphide ore mass and in the upper horizons. It is important to attract the highest amount of gold to the whole chalcopyrite-sphalerite ores, but the lowest amount to their impregnation type. The average amount of gold and silver is higher in ores rich in copper and zinc, but no clear correlation has been identified between these metals and precious metals. The minimum amount of gold is observed in buried side of the ore stock and in the lower horizons where impregnation ores of copper and sulfur pyrite are developed.

Geochemical investigation has been carried out since 2006 to determine the prospectivity of deposits and occurrences formed in deep horizons of the ore region and to assess the reserves of useful components.

Interpretation of geochemical data obtained in the region shows that ore-controlling and parallel faults were observed against the background of anomalies. According to this fact, perspective areas of gold, silver, zinc and other elements can be expected in the region.

According to the results of wells drilled in Gadir deposit, hurricane indications of Au and Ag are observed at certain depths and show the prospectivity of the field in deeper horizons.

As a result of geochemical work in the Maarif deposit, anomalies of Cu and Mo were identified. Geophysical research works have also been carried out and geochemical anomalies have been confirmed in the field to determine how deep geochemical anomalies penetrate.

Copper-zinc mineralization has been identified at a depth horizon of 10m from the ground in the Artapa area. The mineralization zone is limited by south-western tectonic displacement. The thickness of the mineralization zone is 8m, the supposed length is up to 14m. The zone extending in a north-western direction turns in the width direction, i.e. in a north-eastern direction. Mineralization consists of sulfides of copper, zinc and other metals.

A high amount of gold is identified in samples taken from the altered rocks in the Cholpan area, as well as in certain wells, and show that the area is prospective.

Mineralization extending to a distance of 0,2-1,2m with a thickness of 0,1-3,0m was determined in the derivative quartzites on the surface in the Koroghlu area. The amount of copper is 0,20-1,28% , molybdenum 0,01-0,2%, gold 0,20-2,36 g/t, silver 0,2-28,0 g/t, lead and zinc respectively 11-5840 g/t and 65-14847 g/t.

So, summarizing the fund and published data, the latest data of the AIMC company, the deposits and occurrences of the Gadabay ore region can be considered prospective. The special Gadabay deposit can be considered as a large deposit consisted of complex ores of noble and rare elements. The carried-out studies confirm that more than 90% of the deposit's reserves consist of striped impregnation gold-porphyry-copper ores (Babazade et al., 2019[33]). A large mass of ore is located in the lenses and the main reserve is in the "high-quality" gold-copper-pyrite ores located close to the surface. Ore-bearing rocks are consisting of derivative quartzites. Subvolcanic rhyolite-dacite porphyries consist of a large stockwork with sulphide mineralization extending in the north-west and south-east at a depth of 240-300m, with a length of more than 1800m and a width of 200-1000m (average 600m).

[33] *Baba-zadeh, V.M. Geochemical anomalies in the NW flank of Gadabay mine (Lesser Caucasus, Azerbaijan) / V.M.Baba-zadeh, A.A.Veliyev, N.A.Imamverdiyev [et al.] // International Journal of Mining Science (IJMS), -2019. volume5, Issue1, p.31-42. ISSN 2454-9460 (Online). www.arcjournals.org. DOI: http://dx.doi.org/10.20431/2454-9460.0501005.*

CHAPTER VI. GENERATION CONDITIONS AND GENERALIZED GENETIC MODEL OF DEPOSITS AND OCCURRENCES OF THE GADABAY ORE REGION

According to the results of geological-exploration and scientific-research works carried out in the Gadabay ore region in recent years, it can be considered that the Gadabay deposit belongs to the high-sulfidation type with Cu-Au-Ag ore. As part of the epithermal system, the main factor is the variation of quartz and argillite in the pores. But the Gadir deposit, which is part of the Gadabay ore region and is located near the Gadabay deposit, belongs to the low sulfidation deposit type with Au-Ag-Zn-Pb mineralization and its main factors are adular-sericite alteration, siliceous agglomerate and quartz-adular type of veins.

The Umid zone can be concerned to epithermal system with a low sulfidation as Gadir deposit. The above-mentioned evidence for the Gadir deposit also concerns to the Umid deposit.

Rza gold (Au-Ag), Giziljadagh zone with sulphur mineralization (Au-Ag-S), Shah Yatag mineralization zone (Au-Ag-Cu), Yukhari Narzan mineralization zone (Au-Ag) in the Ughur area belong to the high sulfidation type.

The generalized genetic model of the Gadabay ore region is given in the example of the better-studied Gadabay deposit.

As mentioned above, the Gadabay deposit is divided into 4 main mineral complexes on the basis of geological surveys: 1-quartz-adular-pyrite; 2-chalcopyrite-sphalerite; 3-late copper formation stage – chalcocite-covellin; 4-galenite-tennantite. These types of mineralization are mainly located in the central part of the deposit, but it is not possible to determine the exact relationship between them.

Isotope data of sulphur and oxygen were used based on the literature to determine the crystallization temperature, chemical formation conditions and source of sulphur of the Gadabay ore.

The indication of $\delta\ ^{34}S$ is 7,9 $<\delta^{34}S<$8.7 ‰ in the barite samples taken from the deep cores, which are spatially related to

pyrite and chalcopyrite. The indication of $\delta^{34}S$ was 17,0 $<\delta^{34}S<$18,5 ‰, i.e. slightly higher in fine-grained barite associated with placer pyrite and sphalerite.

The indication of $\delta\ ^{34}S$ varies in a narrow range: 2.5 $<\delta^{34}S<$4.0 ‰ in pyrite taken from quartz-adular-pyrite and iron-rich chalcopyrite-sphalerite stages. The indication of $\delta\ ^{34}S$ was -1,2 $<\delta^{34}S<$-1,0 ‰ in the pyrite formed in the chalcopyrite-sphalerite stage, which is poor in iron. According to this pyrite, the indication of $\delta\ ^{34}S$ also varies in a narrow range in sphalerite and chalcopyrite: -0.2 $<\delta^{34}S<$2.2 ‰.

$\delta\ ^{34}S$ indications show that all analyzed sulphides (except pyrite in equilibrium with low-iron sphalerite) are formed from a system in which sulphur predominates in the form of H_2S in the liquid. The average indication of $\delta\ ^{34}S$ in sulfides (usually ranging from -3 to +9 ‰) indicates that the source of sulphur may be either a magmatic source or a magmatic liquid formed by the dissolution of magnesium sulphides (Ohmoto and Goldhaber, 1997[34]).

It can be assumed for the Gadabay deposit that as a result of the rise of the Gadabay intrusion, the depression of ore material happened again from the primary aureole to the rhyolite layer and industrial ores were extracted after the rise of subvolcanic bodies at the end of the Bajocian cycle.

Mineralization in the ore region has been formed over a wide period of time. A number of deposits (Bittibulag) were formed in andesite and andesibasalt complexes in the early Bajocian and due to the formation of late subvolcanic formations in the Bathonian period (Artapa). Most of the deposits (Gadabay) were formed in the late Bajocian when subvolcanic acid rhyolites formed.

Analyzing the literature, it can be concluded that the ore-forming temperature of the Gadabay deposit is 350-3000°C for early mineral paragenesis and 300-1500°C for late stage.

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[34] *Ohmoto,H,Goldhaber, M.B.Sulfur and carbon isotopes // Geochemistry of hydrothermal ore deposits, - 1997. v.3, - p.517-600.*

The depth of ore formation of the Gadabay deposit (depth of ore body formation during the ore formation period from the surface) was 200-500m and the vertical amplitude of ore formation was 1,0-1,5km due to the relation of pre-ore and post-ore dykes with the subsurface rocks that cover it during ore formation. The thickness of andesibasalt subsurface rocks covering the ore body does not exceed the first hundred meters. At the same time, mineralization varies steadily up to 700-800m in the Gadabay ore region. In other words, the depth of ore formation (300 and more) corresponds to the subvolcanic level of epithermal deposits.

There are different opinions about the formation of the Gadabay ore region, including the special Gadabay deposit.

According to V.M.Baba-zadeh and others (2012[21], 2015[22], 2020[23]), the Gadabay ore magmatic system is a typical model, belongs to the deposits of the pyrite family and the source of the ore material is most likely the basitic crust. This is evidenced by the low indication of the heavy isotope of sulphur ($\delta\ ^{34}S$ = 1,5 ‰) and the high amount of subcrystal elements (Ni, Co, etc.) in samples taken from the root parts of the deposit. The beginning of the formation temperature of the productive chalcopyrite-pyrite-sphalerite association corresponds to T = 350-4000°C and decreases to 2000°C at the end of the stage. According to these authors, this deposit has a complex polygenic-polychronous nature, in addition gold-sulphide-quartz mineralization. Gold is in the form of thin dispersions, gold- and silver-bearing quartz veins are not typical for this deposit.

These authors proposed another model for the Bitti-Bulag ore magmatic system. So, the hydrothermal-metasomatic gold-pyrite-enargite ores here are related to the stockwork ores of the copper-porphyry formation, which lies deeper in the single ore-magmatic system at the subvolcanic level (Lower Bajocian). The homogenization temperature is 260-2800°C in pyrite-enargite ores, $\delta\ ^{34}S$ fractionation shifts to the heavy isotope side (4,5 ‰ to 15 ‰ and more) (Baba-zadeh et al., 2015[22]).

L. Eppelbaum and Hesin (2012[35]) believe that the Gadabay deposit was formed in two stages. Sulphide (pyrite or quartz-adular-pyrite association), which is associated with the Late Bajocian subvolcanic rhyolite-dasite bodies, was formed in the first stage. As a result of postmagmatic activity of Gadabay intrusive, copper-pyrite, copper-zinc mineralization (chalcopyrite-sphalerite mineralization) was formed in the second stage. The isotope of sulphur varies in a narrow range ($2,5 < \delta\ ^{34}S < 4$ ‰) in sulfides in both mineralization stages. This indicates that they were both formed from the same solution under restorative conditions.

But, it is not clear from their model whether mineralization with low sulfidation (quartz-adular-pyrite association by predomination of chalcopyrite and sphalerite) and mineralization with high sulfidation (formation of copper at the late stage) are related to the same continuous or different processes?

Epithermal deposits with low, medium, and high sulfidation have been described under convergent conditions of plates (e.g., Sillitoe & Hedenquist, 2003[36]). But, these types of epithermal deposits are specific to different processes (Sillitoe & Hedenquist, 2003[36]; Simmons et al., 2005[37]).

So, it can be noted that mineralization with the high and low sulfidation in the Gadabay ore region is associated with two different processes that are spatially close, but have different genesis. The deposit is mainly represented by quartz-adular-pyrite alteration and local mineralization through predominance of chalcopyrite-sphalerite (related to iron sphalerite). Other types of mineralization are insufficient in volume and are observed only in the central part of the

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[35] *Eppelbaum,L,Khesin,B.Tectonical-Geophysical Setting of the Caucasus // Geophysical Studies in the Caucasus, - 2012. - p.5-37.*

[36] *Sillitoe, R.H., Hedenquist, J.W. Linkages between volcanotectonic settings, ore-fluid compositions, and epithermal precious metal deposits // Special Publication-Society of Economic Geologists, - 2003. v . 10, - p.315-343.*

[37] *Simmons, S.F., White, N.C., John, D.A. Geological characteristics of epithermal precious and base metal deposits // Economic Geology, - 2005. 100th Anniversary Volume, - p. 485-522.*

deposit. In general, the hydrothermal environment of the Gadabay deposit can be considered neutral (presence of adular) and restorative (pyrrhotine inclusions, data of sulphur isotope). It can be assumed that the deposit had favorable conditions for gold to remain in solution. As mentioned above, this can occur in the Gadabay epithermal system at temperatures between 300 and 1500°C.

Unfortunately, there is no evidence to explain the sedimentary mechanism of gold. Sander and Eynaudi (1990[38]) explain the sedimentation of gold for the Round Mountain (USA) by two processes: 1- slow cooling in the main hydrothermal basin and sedimentation of low-quality but large amount of gold with quartz and adular and 2- local mixing of gold with meteoric waters, which causes a large amount of sedimentation. According to these authors, the sedimentation of gold occurs at a temperature transition from 2500°C to 2000°C. The slow cooling of the system creates condition for sedimentation of gold by maintaining a balance with quartz, adular and pyrite.

In our opinion, these mechanisms can be applied to the Gadabay deposit.

The sedimentation of low-quality gold (<1 g/t) in the Gadabay deposit due to quartz-adular-pyrite alteration can also be explained by the gradual cooling in the hydrothermal basin. As noted by Sander and Eynaudi (1990[38]), the local oxidation of a hydrothermal basin by mixing it with meteor water causes for the formation of a high-quality ore body. Indeed, high-quality mineralization in the Gadabay deposit is associated with fault structures in the central part of the field, especially the Gadabay-Bittibulag fault. Over time, mineralization has increased in the central part of the field in evolution, i.e. from restorative condition to oxidative conditions. The deposits and occurrences on the north-western flank of the Filiz region (Gadir, Ughur, Umid, Cholpan, Giziljadagh, Bittibulag) are

[38] *Sander, M.V., Einaudi, M.T. Epithermal deposition of gold during transition from propylitic to potassic alteration at Round Mountain, Neveada // Economic Geology, - 1990. v.85, - p. 285-311.*

also associated with this deep fault and it can be assumed about the formation of their mineralization through forming in a similar way.

So, most deposits and occurrences of the Gadabay epithermal system are associated with the Gadabay-Bittibulag deep fault and are prospective for mineralization. The recent geological exploration and geochemical investigations show that the horst zones in the region are more perspective for ore mineralization.

CONCLUSION AND SUGGESTIONS

1. The Gadabay deposit can be considered to belong to the high sulfidation type with Cu-Au-Ag mineralization. As part of the epithermal system, its main factor is the change of quartz and argillizite in the cavities. This type also includes deposits and mineralization zones found in the Ughur zone. The Gadir deposit and the Umid zone, which are part of the Gadabay ore region, belong to the low sulfidation type with Au-Ag-Zn-Pb mineralization and the main factors are adular-sericite variation, siliceous agglomerate and quartz-adular type of veins. Enrichment with flying components (Te, Se, Hg, Sb, As) is typical for the epithermal environment [5, 13, 17, 21].

2. Mineralization in the Gadabay deposit took place in 4 paragenetic sequences: 1) quartz-adular-pyrite formed by the change of andesite tuffs forming mineralization in the form of semi-massive sulfide lenses; 2) localized chalcopyrite and sphalerite mineralization in the form of semi-massive lenses and veins; 3) later stage of formation of copper mineral in which chalcopyrite and sphalerite are replaced by chalcosine, covellin and enargite; 4) galenite-tennantite formed at different times [1, 2, 8, 9, 14].

3. Mineralization has occurred over a wide time range in the ore region. A number of deposits (Bittibulag) were formed due to the formation of late subvolcanic structures in andesite and andesite-basalt complexes in the early Bajocian and in the Bathonian age (Ertepe). Most of the deposits (Gadabay) were formed when subvolcanic acid rhyolites rose in the late Bajocian [3, 6, 11].

4. The ore formation temperature of the Gadabay deposit is 350-3000° C for early mineral paragenesis and 300-1500° C for the late stage [15, 19, 20].

5. Geochemical investigations in the north-western flank of the Gadabay deposit have confirmed the existence of prospective ore deposits for gold, silver, zinc and copper. Au-Sb-Bi-Th-Ce-Zr anomalies have been determined in areas such as Gadir, Umid, Mubariz, Zafar, Rza, Ugur in the north-east-south-west direction and are controlled by mineralization along faults in these areas [7, 10, 13, 14, 18, 21].

6. The results of the analysis of samples taken from the earth's surface, surface mountain excavations, geological-exploration wells show that the Gadabay epithermal system is prospective towards the flanks and depths. It is proposed to continue accurate exploration works in these areas in the future [4, 7, 8, 12].

7. It is suggested to carry out detailed geological, structural and cartographic works in the deposits and manifestations discovered in the Gadabay ore region (on a scale of 1: 1000); to take geochemical samples (in an area of 1 km^2, in 50x50 network); to carry out geophysical and magnetometric profiling works on the scale of 1: 2000 in case of geochemical anomalies; to drill wells in case of geochemical and geophysical anomalies [15, 16, 21].

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3. Deposits of noble and non-ferrous metals of the Gadabay ore region, perspectives for their search // News of Baku University, series of natural sciences, 2012, No. 3, pp.117-133 (co-authors: Ramazanov V.G., Robert Morits, Galandarov B.H., Mansurov M.I.). (in Russian)

4. Geological interpretation of the results of geophysical and geochemical studies carried out within the Gadabay ore region // Baku University News, Natural Sciences Series, 2012, No. 3, pp.134-140 (co-author: Mehdi Safari). (in Russian)

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