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GOLD-BEARING VOLCANOGENIC FIELDS OF NON-FERROUS METALS OF THE LESSER CAUCASUS AND THE EASTERN PONTIDES AND THEIR GENESIS

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Summary. In the countries of the South Caucasus and Türkiye, the most representative gold-bearing volcanogenic fields are known in the strata composing fragments of the Pontic-South Caucasian paleoarc, which was active during the Mesozoic Era. At that time, the oceanic crust was subducted under the arc, which was the marginal part of the Eurasian continent. Separate segments of the arc differed in their geodynamic development, due to which different types of volcanogenic fields occurred in them. Besides epigenetic deposits, hydrothermal-sedimentary deposits are also known within the Pontides (Türkiye) in the west.

The paper deals with the geological environments of deposits' occurrence in Türkiye, Azerbaijan, Armenia and Georgia. Most of them can be attributed to the Kuroko type and differ in the nature of ore accumulation: copper-zinc deposits, which were apparently formed in the conditions of a deep-sea basin, are known in Türkiye, and we have examples of only epigenetic fields to the east. The Gadabay and Alaverdi ore regions are interesting in that copper, copper-zinc and barite-sulfide ores are concentrated in the Jurassic volcanic depressions, and porphyry copper fields – Garadag and Tutkhun are known in the raised wedge-shaped blocks that limit the volcanic depressions. A mental logical geological and genetic model of volcanogenic fields was created based on the literary material, which has been collected for years, as well as our own data.

Fields of volcanogenic nature, despite the fact that they are formed in similar PTX conditions, have their own "appearance", taking into account which is extremely important when predicting fields in specific areas.

Introduction

The Caucasian folded mountain structure is perceived as the result of interaction of microcontinents – "fragments" of the Afro-Arabian and Eurasian lithosphere plates. As a rule, the marginal parts of microcontinents are composed of sediments of either marginal marine or oceanic origin that obducted on them (Fig. 1). According to the composition of the lithogeodynamic complexes, the southern margin of the European continent was occupied by an oceanic basin (Paleotethys) at the beginning of the Hercynian cycle, covering the time from the Silurian to the Early Triassic inclusive, as evidenced by the North Caucasian ophiolitic allochthons, Silurian-Devonian deepwater carbonaceous siliceous-argillaceous strata, as well as volcanites of the Front Range zone of the Greater Caucasus, which most likely belong to the formations of the ensimatic arc (fragments of which are exposed in the modern zone of the Main Range of the Greater Caucasus) based on the predominance of basites in them. There was obviously an ensialic arc to the south of the latter, on the slopes of which flyschoids accumulated during the Devonian-Carboniferous, and its root underwent metamorphism and granitization. It is assumed that part of Gondwana (in Fig. 1 – Taurides and Daralagoz block) was "soldered" to Eurasia at the end of the Triassic, and later – at the beginning of the Jurassic – torn away due to the laying of the Lesser Caucasus branch of the Neotethys. The diagram (see Fig. 1) shows that the central part of the Alpine-Himalayan mountain-fold belt consists of microplates: 1) Scythian and South Caucasian-Pontic (active paleomargin of the Eurasian continent); 2) Kirshehir, Taurus and Daralagoz blocks (previously part of Gondwana). The continental blocks are separated by suture zones (sutures), most of which are marked by ultramafic "mélange". Passive continental blocks of Gondwana appear to researchers (Vrielinck, 1994) drifted on oceanic lithospheric plates.

It follows from numerous publications (Адамия и др., 1977; Шихалибейли, 1996; Okay, Sahinturk, 1997; Sosson et al., 2010; Vrielinck, 1994; Yilmaz et.al., 1997) that the most important tectonic events that predetermined the geological appearance of the Alpides include: 1) the abruption of the Iranian plate in the Permian-Triassic from the edge of Gondwana and its joining to the active Eurasian margin; 2) opening of the Neotethys at the Late Triassic-Early Jurassic, possibly its two branches (Biju-Duval et.al., 1997) in connection with the laying of rift systems; obduction of oceanic complexes in the Senonian, as A. Knipper (Монин, Зоненшайн, 1987) put it figuratively, denoting the "death" of the ocean. Due to the abovementioned events, the main milestones of the historical and geological development in the Alpine cycle were also emphasized: the divergence of microplates (Triassic-Early Bajocian), accompanied by the formation of the Neotethys branches and the activation of mantle diapirism at the beginning; then their convergence (Late Bajocian-Early Cretaceous) with characteristic island-arc andesitoid volcanism on the edge and rift-related volcanism in the central part of the South Caucasus-Pontic microplate. Moreover, the maximum activation of island-arc volcanism in Transcaucasia falls on the Bajocian-Late Jurassic, and in the Pontides – on the Turonian-Santonian. Based on comparative structural-facies analysis, A. Yilmaz et al. (Yilmaz et.al, 2000) showed the difference in the geodynamic development of individual segments of the South Caucasus-Pontic system. The beginning of the collision (or the beginning of the collision of continental protrusions of microplates) in the western and eastern parts of the region was diachronous: if the "contact" of the South Caucasian and Daralagoz blocks occurred in the Coniacian (Монин, Зоненшайн, 1987), then the Pontides with the Taurida occurred in the Campanian (Dixon, Periere, 1974). Volcanic activity was occurred in the residual back-arc sea basins at the collision stage (Late Cretaceous-Eocene), and later in the depressions (Eocene volcanites) formed on the previously formed tectonic structures.

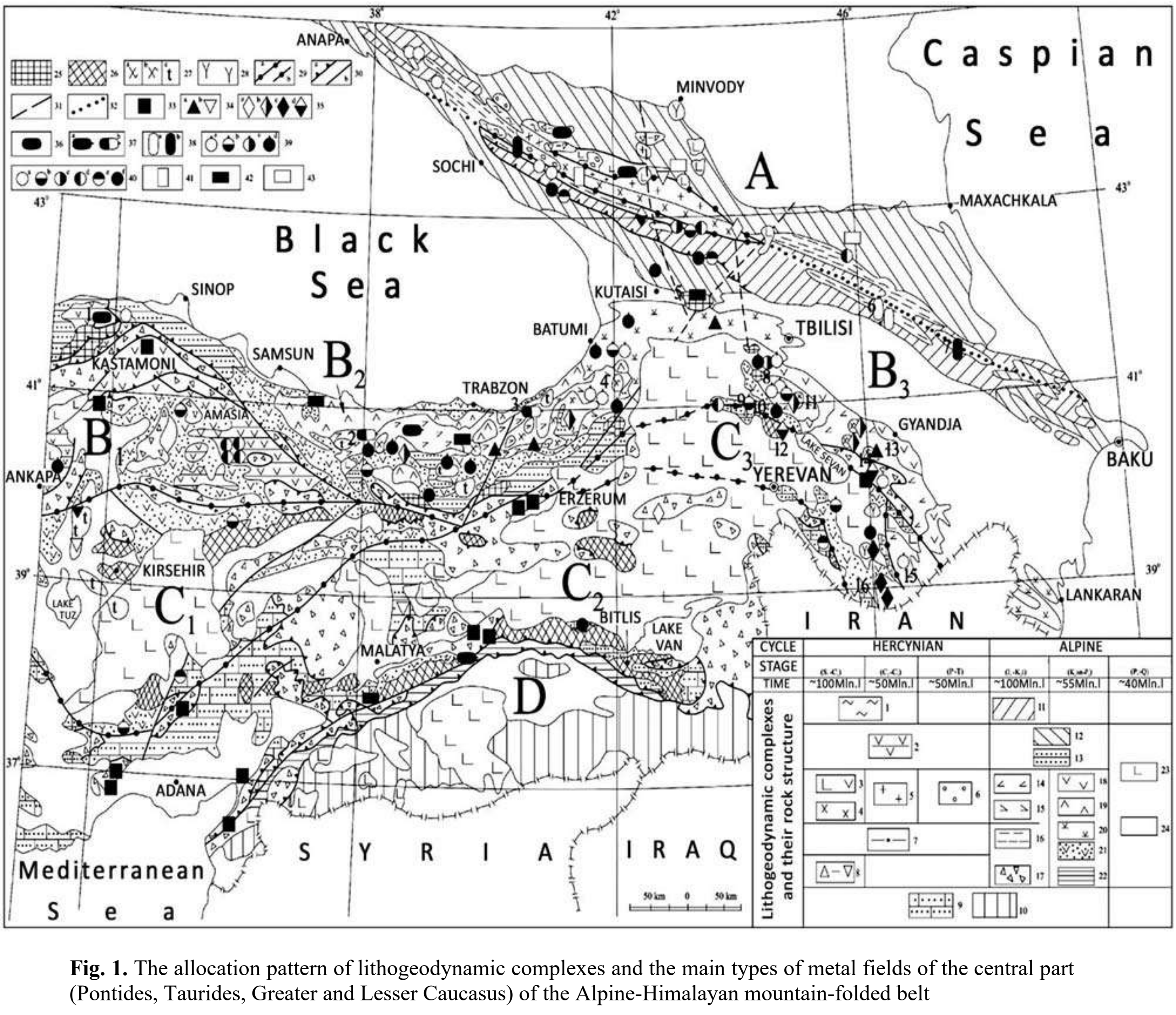

Fig. 1. The allocation pattern of lithogeodynamic complexes and the main types of metal fields of the central part (Pontides, Taurides, Greater and Lesser Caucasus) of the Alpine-Himalayan mountain-folded belt

Hercynian lithogeodynamic complexes: *active margin of the East European paleocontinent*: 1 - continental shelf zones and slopes (andesite-basalts, carbonaceous shales, limestones, Devon-Carbon, greenstone alterations, Greater Caucasus); 2 - continental shelf zones (sandstones, conglomerates, carbonaceous shales, andesite-basalts, Carboniferous-Triassic, greenstone alterations, Pontides); 3 - ensimatic island arc (basalts, rhyolites, siliceous shales, carbonate-rich sandstones, Devonian-Early Carboniferous, Greater Caucasus); 4 - ensialic island arc (gabbros, sodium granitoids, parametamorphites and crystalline schists, Pre-cambrian (?) – Early Paleozoic, Greater Caucasus); 5 - activated blocks of the ensialic arc (collisional potassium-sodium granitoids, staurolite and biotite-muscovite schists, late Paleozoic, Greater Caucasus); 6 - continental depressions (clay shales, sandstones, andesite-basalts, rhyolites, Permian-Triassic, Greater Caucasus); 7 - paleomarginal sea - slope and plain of the continent (carbonaceous shales, sandstones, andesite-basalts, olistostromes, limestones, Devonian-Triassic, greenstone alteration, southern slope of the Greater Caucasus); 8 - ocean floor (carbonate and siliceous shales, basalts, peridotites, dunites, rhyolites – in allochthonous occurrence, Greater Caucasus); *passive margin of Gondwana, and in the Mesozoic Afro-Arabian, paleocontinent*: 9 - shelf zones (clays, carbonate clays and sandstones, limestones, locally andesite-basalts, tuffites, Paleozoic-Cretaceous, Kirshehir, Taurus and Daralagoz blocks); 10 - shelf and continental zones of the Arabian uplift (sandstones, clays, limestones, conglomerates, Paleozoic-Eocene).

Alpine lithogeodynamic: active margin of the Eurasian paleocontinent: 11 - slopes and plain of the South Caucasian microcontinent (andesite-basalts, trachyandesites, terrigenous-carbonate flysch, carbonaceous clay shales, granodiorites, Jurassic-Early Cretaceous, southern slope of the Greater Caucasus); 12 - shelf zones of the Scythian and South Caucasian microcontinents (andesites, andesite-basalts, clay shales, sandstones, mottled clays with sulfates, limestones and dolomites, marls, tuffites, Jurassic-Paleogene, Greater Caucasus); 13 - shelf zones and slope of the Pontian microcontinent (andesite-basalts, sandstones, limestones, shales, Early Jurassic; conglomerates, limestones, basalts, coral rag, marls, Late Jurassic-Cretaceous; terrigenous-carbonate flysch, Late Cretaceous, Pontides); 14 - Lesser Caucasus ensimatic island arc (andesite-basalts, rhyodacites, tuffites, sandstones, clay shales, tonalites, diorites, Bajocian-Early Cretaceous, southern edge of the Transcaucasian microcontinent); 15 - Pontian ensimatic island arc (andesite-basalts, rhyodacites, marls, sandstones, clay shales, Late Cretaceous (Turonian-Santonian), Eastern Pontides); 16 - basins of the marginal paleosea (clay shales, basalts, rhyolites, gabbro-diabases, Early Jurassic, Greater Caucasus); 17 - oceanic zones in allochthonous bedding (in the composition of sutures and obducted thrust plate – ultramafic "mélange", harzburgites, serpentinites, gabbros, tholeitic and alkaline basalts, terrigenous-carbonate flysch with horizons of ophioclastic olistostromes, radiolarites; Pontides, Taurides and Lesser Caucasus); 18 - Lesser Caucasus residual back-arc volcanic depressions (andesites, rhyodacitic ignimbrites, rhyolites, trachyrhyolites, limestones, basalts, granodiorites, Senonian-Danian); 19 - Pontic residual back-arc volcanic depressions (basalts, rhyodacites, trachyrhyolites, coral rags, Campanian-Danian); 20 - intraplate rift-related volcanic depressions (trachyandesites, trachybasalts, volcanogenic-terrigenous flysch with olistostrome horizons, gabbro-diorites, monzonites, syenites, alkaline gabbroids and syenites, Eocene, Lesser Caucasus and Pontides); 21 - superimposed, mainly on pre-collision structures, marine volcanic depressions (andesites, trachyandesites, terrigenous-carbonate flysch, sandstones, clays, Eocene; Pontides, Taurida and Lesser Caucasus); 22 - flysch troughs (southern side of Taurus), formed at the beginning of the collision of the Taurus microcontinent with the Eurasian continent (sandstones, marls, clays, fragments of ultramafic, Senonian-Paleogene); 23 - activated blocks of folded mountain structures (andesites, andesite basalts, their pyroclastolites, Neogene-Quaternary); 24 - intermountain and foredeeps of folded mountain structures (marine and continental molasses, Oligocene-Quaternary); 25 - Crystalline basement of the Eurasian continent (Precambrian-Early Paleozoic); 26 - Crystalline basement of the Afro-Arabian continent (Precambrian); 27 - Granitoids (pre-collision: a- Early Cretaceous, b- Late Cretaceous; c- collision Eocene-Oligocene); 28 - Post-collision monzonites, syenites, granodiorites; 29 - Sutures (a- known, b- inferred under recent deposits); 30 - Ruptured zone (a-thrust and reverse-thrust faults, b-near-vertical faults); 31 - Caucasian lineaments based on the results of interpretation of space images; 32 - supposed boundary between the Scythian and Transcaucasian microplates.

Genetic types of fields: 33 - magmatic (chrome raw materials); 34 - skarn (a- iron ore, b- tungsten-molybdenum); 35 - hydrothermal plutonogenic (a-polymetallic, b- copper-porphyry, c- copper-molybdenum-porphyry, d- gold ore); 36 - hydrothermal-sedimentary in volcanic strata (copper with zinc); 37 - combined hydrothermal-sedimentary and epigenetic (stockwork) in volcanic strata (a-copper, b-copper-zinc); 38 - hydrothermal-sedimentary in clayey-shale strata (a- polymetallic, b- copper); 39 -

hydrothermal epigenetic in volcanic strata (a- copper; b- polymetallic with baryte; c- polyformational: copper, baryte, baryte-polymetallic, gold ore in secondary quartzites; d- properly gold ore); 40 - amagmatogenic ("telethermal") (a- mercury, b- arsenic (realgar-orpiment), c- arsenic (arsenopyrite with gold), d- gold with antimony, e- lead-zinc in carbonate strata, f-baryte); 41 - hydrothermal-metamorphogenic (tungsten); 42 - sedimentary and volcanogenic-sedimentary (manganese); 43 - sedimentary (celestine).

Significant fields of the Eurasian active paleoomargin: 1 - Ashikei (Cu), 2 - Lahanos (Cu, Zn, Pb), 3- Chayeli-Madenkoy (Cu, Zn), 4 - Murgul (Cu, Zn), 5 - Chiatura (Mn), 6 - Filizchai (Zn, Pb, Cu), 7 - Gizil-Dere (Cu), 8 - Madneuli (Cu, Zn, Pb, Au, $BaSO_4$), 9 - Alaverdi (Cu), 10 - Shamlug (Cu), 11 - Tekhut (Cu), 12 - Meghradzor (Au), 13 - Dashkesan (Fe,Co), 14 - Chovdar $BaSO_4$, 15 - Chovdar (Au), 16 - Zod (Au), 17 - Kafan (Cu), 18 - Kajaran (Mo, Cu).

Microplates: Eurasian paleocontinent: A - Scythian, B - Pontic-South Caucasian (B_1- Western Pontides, B_2 - Eastern Pontides, B_3 - South Caucasus); Afro-Arabian paleocontinent: C_1 - Kirshehir, C_2 - Taurus, C_3 - Daralagoz (North Iranian). Microplates are separated by sutures. D - Arabian ledge (its boundary with the Taurus is emphasized by a system of reverse-thrust faults).

The Caucasus is a relatively well-studied region and therefore it can be stated that its ore potential is determined by: plutonogenic hydrothermal (copper, molybdenum, gold), volcanogenic hydrothermal-sedimentary (copper, zinc, lead), volcanogenic epigenetic (copper, zinc, gold, barium), skarn (tungsten, molybdenum, iron) and sedimentary (manganese, strontium) fields. Besides that, "amagmatic" mercury, arsenic, antimony and lead-zinc (in carbonate strata), magmatogenic (chromium, titanium), pegmatoid (tin), greisen (niobium, tantalum) fields and ore occurrences are known here. Epigenetic gold-bearing volcanogenic fields of copper and baryte-polymetallic (Gadabay, Bitti-Bulag, Novo-Gorelovka, Gulyatag, Janyataq, Kapaz, Alaverdi, Shamlug, Kafan, Akhtala) first (Jurassic) occurred during the convergence of microplates in the folded mountain structure of the Lesser Caucasus, and copper-porphyry fields of the Garadag, Damirli, Tekhut types in the Early Cretaceous (Абдуллаева, 2013, 2018; Баба-заде др., 2003, 2012). All of them were observed in Azerbaijan and Armenia. Epigenetic copper, gold, baryte-polymetallic fields such as Bolnisi (Georgia), Dagkesaman (Azerbaijan), etc. were formed in the back-arc volcano-depressions at the early stage of the activated collision. In the west, in the Eastern Pontides in the Late Cretaceous, volcanogenic-sedimentary copper-zinc ores (Chayeli and others, Türkiye) accumulated in intra-arc sea basins, and large-scale Murgul and other epigenetic ores fields were formed.

The fields show clear connections with certain volcanites and lithogeodynamic complexes of paleo-island-arc structures.

It is well known that ore fields are located in the upper, 10-kilometer "edge" of the Earth's crust. The topmost position is occupied by volcanogenic fields of non-ferrous and precious metals (0 - 1 km). They will be discussed in this article. The geological positions of the fields of the Eastern Pontides (Türkiye), Bolnisi (Georgia), Gadabay (Azerbaijan) and Alaverdi ore regions, as well as the copper-porphyry fields of Garadag and Tekhut, located in raised blocks near the Gadabay and Alaverdi (Armenia) gold-copper pyrite volcanogenic fields will be given as examples.

Eastern Pontides (Türkiye) and their ore-bearing

It has been found that volcano-plutonic activity led to the formation of significant accumulations of gold-bearing volcanogenic and plutonogenic ores of non-ferrous metals in the Eastern Pontides (Türkiye), which developed in the Alpine period as an island paleoarc. Moreover, volcanogenic fields were formed in volcano-depressions, which were parts of intra-arc sea basins in the Cenomanian-Campanian, and plutonogenic copper- and molybdenum-porphyry fields were formed due to the formation of granitoids in blocks raised relative to the depressions. Commercial fields are Ashikoy, Lahanos, Kutlular, Chayeli, Murgul, Cherratepe and Guzeyyayla (Cu, Mo). It should be emphasized that the Eastern Pontides are the only region of the Pontic-South Caucasian island paleoarc where hydrothermal-sedimentary accumulations of non-ferrous metal ores have been observed. Examples of these are the Chayeli (Madenkoy) and Ashikoy fields. The Chayeli field, which geologists call the pearl of the Pontides, contains significant reserves of non-ferrous metals. The massive sulphide ores (VMS) form a deposit with 920 m long (along the strike) here; it is traced to a depth of 650 m; its maximum thickness is 100 m. The deposit is covered by thin (up to 2 m) jasperlike quartzites as in the field of Kuroko type in Japan. This layer is covered by a series of interbedded tuffites and basalt covers, above which lie green tuffs with dolomite interlayers containing foraminifera fragments. According to Turkish geologists, the deposit is divided into two parts by a syn-ore fault. In connection with it, the body consists of two mutually overlapping "lenses". Sulfides are represented by pyrite, chalcopyrite, sphalerite and in small quantities galena, bornite, tetrahedrite. Yellow (rich in chalcopyrite) and black (rich in sphalerite) ores are distinguished inside the body, as in the fields of Kuroko type. The sphalerite content exceeds 10% in the matrix of brecciated black ores. Veinlet-impregnated mineralization occurs in dacites under the massive ore deposit. The hydrothermal-sedimentary structure, which was preserved in the Late Cretaceous volcanites as an ore deposit, was subjected to repeated brecciation under the influence of explosive phenomena during the functioning the hydrosystem. Clastic ores are predominantly located in the upper parts of the deposit. Massive yellow ores and their powdery varieties form the lower parts of the body and are characteristic of the most powerful parts of the deposit. Massive ores superpose on hyaloclastites, which consist mainly of oriented felsite “fragments”. The abovementioned rocks are overlain by a quartz-pyrite-chalcopyrite stockwork.

Another type of hydrothermal-sedimentary mineralization was found in the allochthon, apparently displaced to the paleoisland structure from the marginal sea basin of the Paleotethys. The rocks that form the allochthon are known in the literature as the “Cure complex”: their age is Triassic, they consist of ultramafic tectonic plates, alternating clay shales and basalt covers, represented by island-arc and oceanic tholeiites, as well as rocks of the depleted mantle. According to Ustaomer (Ustaomer, Roberston, 1993), a geological picture similar to the Cyprus one is observed in places where ore mineralization occurs: serpentized peridotites are known in the lower part of the section, above which gabbro, a shale dolerite complex and greenstone-altered pillow lavas of basalts are occurred. The lavas that enclose the dolerite dykes are covered by clay shales. Copper-bearing massive sulphide deposits are located under the latter, on pillow lavas. One should agree with M. Guner, who attributed sulphur pyrite deposits refined with copper to the Cyprus VMS type.

Epigenetic sphalerite-chalcopyrite mineralization is observed at other exploited fields of the Pontides.

The Turkish and Western European geologists' works deal with the composition and structure of volcanic strata hosting non-ferrous metal fields in the Eastern Pontides (Altun, 1977; Akchay, Arar, 1999; etc.). The base for the Late Cretaceous rocks-carriers of the fields are andesitic volcanites and Lower-Middle Jurassic terrigenous rocks (Popović, 2004), as well as the Upper Jurassic-Cretaceous complex with minor copper and gold occurrences.

According to Akchay (Akchay, Arar, 1999), bimodal volcanites, in which VMS are located, are associated with large calderas and siliceous domes. VMS were also known at the Murgul, Jerattepe, Kutluler, Kotarakdere, Hrzit and Lahanos fields. It follows from the archive and published materials that the massive non-ferrous metal ores of the Pontides were formed on the seabed of deep-sea basins, and before the diagenetic transformation of the sediments, the ore deposits were “ore hills”. The sea basins were probably intra-arc, and their bottoms underwent rifting in the Late Cretaceous, as evidenced by the composition of the volcanites, as well as basalt dikes that intersect both the ore deposit and the upper basalts and purple tuffs. The rocks overlying the Chayeli ore deposit alter little, except for diagenetic alterations. Senonian fauna was found in the pink limestones of the upper series.

Massive ores are gold-bearing: gold is found in sphalerite in the form of inclusions with size of 200 μ. Researchers see vertical, poorly expressed zoning (from top to bottom) in the ore deposit: sphalerite-galena-baryte-chalcopyrite; pyrite-chalcopyrite-clay; pyrite-chalcopyrite-quartz.

It was found that the basalts of the ophiolite complex belong to the formations of spreading zones according to their chemical characteristics in the Kure region, at the Ashikoy-Taikopdu field (Chakir, 1995). It is assumed that the spreading zone was located in a back-arc basin in the Early Jurassic.

Examples of stockwork-vein fields, very similar to the Madneuli copper ores (Georgia), are in the Pontides – Lahanos and Murgul, associated with late Cretaceous volcanites. Hydrothermal-sedimentary deposits with “black” and “yellow” ores are known near Murgul, in the Gizilgaya area (Lethch, 1981), which were characterized by colloform banded and framboidal textures. The ore-bearing rocks with angular unconformity are overlain by andesite-dacite lavas here.

In conclusion, we state that gold occurrences are also known in the Eastern Pontides, for example, Behkesik (Yigit et al., 2000) and Maradit (Popović, 2004) in Late Cretaceous volcanites, as well as in Eocene quartz diorites. The commercial value of gold occurrences has yet to be determined.

Bolnisi ore region (Georgia) and its ore-bearing

The Cretaceous volcano-tectonic depression of the Bolnisi ore region was laid in the back-arc residual sea basin at the end of convergence, and was finally formed at the beginning of the collision of the South Caucasian and Iranian lithospheric microplates. The depression is filled with Albian-Campanian volcanogenic-terrigenous deposits, within which three complexes are distinguished (Назаров, 1966; Кекелия и др., 1993; Гугушвили и др., 2002, 2018; Баба-заде и др., 2015).

In the opinion of the authors (Назаров, 1966), copper, baryte-polymetallic and gold (in secondary quartzites) mineralizations of different ages are combined at the largest Madneuli field, where initially only baryte and later copper and gold ores were mined: at the small Tsitelisopelskoye - copper and gold, at Sakdriskoye – gold and baryte-polymetallic; at David - Garejinskoye – baryte, baryte-polymetallic and gold-silver. The example of Madneuli (Кекелия и др., 1991, 1993) shows that ore accumulation was preceded by the stage of formation of a metasomatic column, the upper parts of which are occupied by monoquartzites – solfataric formations, the lower ones – by quartz-sericite metasomatites, and the flanks and deep horizons – by propylites. Two ore levels are clearly distinguished under the screen of lava domes at Madneuli (Кекелия и др., 1993): the upper one is baryte and baryte-polymetallic, and the lower one is copper-pyrite. Gold-bearing quartzite bodies are occurred on the upper and partially lower layers.

Georgian geologists have carried out a large volume of thermobarogeochemical studies at the fields of Bolnisi region. According to previous researchers (Аревадзе, 1989; Kekeliya et al., 1993), two-phase gas-liquid inclusions in quartz of copper pyrite ores were homogenized at 320-370°C (maximums – 350-420°C), copper-zinc ores at 280-300°C, in baryte of polymetallic barytes at 260-270°C, and in barytes of baryte ores proper at 120°C. According to cryometric studies of fluid inclusions, the salinity of the solutions that deposited copper and polymetallic ores was low and equal to ~ 40 gram-equivalent of NaCl per liter of solution. The solutions were chloride-sulfate potassium-sodium, contained nitrogen and CO_2. Heavy hydrocarbons and methane were also observed (Кекелия и др., 1993), the total concentration of which did not exceed 4 mol%. The data on the isotopic composition of sulfur are following: the $\delta^{34}S$ values deviate slightly from the meteoritic standard in sulfides: the $\delta^{34}S$ values fluctuate within the range of +10 to +20% in most sulfates. Data on carbon, hydrogen and oxygen isotopes are ambiguous and can be interpreted in favor of the participation of both meteoric and magmatic waters during the ore-forming process. So, the values of $\delta\ ^{13}C$ in calcite and fluid inclusions are grouped around the values of -7.1 ±2.1% and +0.3 ±1.6%; the isotopic composition of hydrogen (δD water) in fluids varies within the range of -70 -90%, and modern waters of the region from -50 to -70%; $\delta\ ^{18}O$ in quartz of copper ores varies from +10.35 to +9.25%, and in baryte of baryte-polymetallic ores within the range of -1.07 to -1.53%.

It should also be stated that industrially significant volcanogenic fields are located in the upper parts of the blocks of Turonian-Santonian effusive-sedimentary rocks in the Bolnisi region, in places where the latter are complicated by extrusive and lava domes. The blocks are bounded by faults of NW and NE strike, which are magma and ore excurrent.

The authors of this paper have data (Гугушвили и др., 2002) on the isotopic composition of strontium and the concentrations of rubidium and strontium in rocks located near volcanogenic fields. It turned out that the basalts of the Bolnisi region ($^{87}Sr/^{86}Sr$ = 0.704910) could be the products of differentiation of the undepleted mantle, and the rhyodacites at the Murgul field (Türkiye) could have originated in the lower crust ($^{87}Sr/^{86}Sr$ = 0.707739); the rhyolites of the Madneuli field - in the lower upper crust ($^{87}Sr/^{86}Sr$=0.710269). The crustal source of the rhyolite and ignimbrite magmas is also indicated by the europium ratios (for rhyolites – Eu/Eu*=0.65-0.68, ignimbrites – 0.52-0.58) established in them, as well as the enrichment of the rocks in light REE and large-ion lithophylic elements.

It seems appropriate to present geochemical data (Гугушвили и др., 2002) on the rocks hosting the Rapu-Rapu field (Philippines), published in the scientific literature (Sherlock et al., 2003). The massive sulphide deposits of the Rapu-Rapu fields are spatially associated with dacites that have undergone greenstone transformation. This field is of the Kuroko type. Researchers (Sherlock et al., 2003) believe that the REE-rich volcanic rocks of the Rapu-Rapu field were formed during the active rifting of an oceanic arc or a Jurassic back-arc basin. It is interesting that there is a known Canatuan field also in the Philippines, which was formed in the environment of an immature arc that is confirmed by a sharp decrease in the content of light REE in acidic and basic rocks. The data presented for the Bolnisi ore region (Гугушвили и др., 2002) shows that the Zr/Y ratios are higher (for dacites 9.5-11.2; for rhyolites 2.7; for basalts 3.7-4.1) and we are probably dealing with a more mature paleo-arc.

Gadabay ore region (Azerbaijan) and its ore-bearing

It is located in the axial zone of the Shamkir horst-uplift, complicated by the Upper Jurassic-Lower Cretaceous Hajikend-Dashkesan superimposed trough. Its disjunctive framework consists of two faulting systems: the early, northwestern and the later, northeastern. The first of them also includes the Main Gadabay Fault zone, which can be traced in the southwest of the region (Абдуллаева, 2013, 2018; Баба-заде, 2003; Баба-заде, Абдуллаева, 2012).

A special place in the structure of the ore region is given to its central part, where the famous Gadabay gold-copper pyrite ore field is located, controlled by a volcano-dome structure and complicated by radial faults. Bitti-Bulag, Novo-Gorelovka, Maskhit and other gold-copper pyrite, gold-copper-arsenic, gold-copper-polymetallic ores fields are also located here, which represent together the Gadabay ore-magmatic system.

The ore bodies of the Gadabay field, described as stocks in the literature, are morphologically more likely to be flat lenticular bodies, which are confined to the upper horizons of the rhyolite and rhyodacites strata. Part of the ore bodies is concentrated in the early Bajocian main volcanites. These strata are broken by dikes associated with the formation of andesite-basalt-plagiorhyolite and basalt-andesite-dacite-rhyolite formations, as well as comagmatic Mesozoic plagiogranites (Atabey-Slavyan intrusion) and gabbro-diorites, quartz-diorites, etc. (Gadabay intrusion), which according to the entire complex of features, can be combined into a volcano-plutonic association.

The main ore bodies of the Gadabay field (Karlshtok, Fedorov-stok) are confined to the most raised parts of the blocks at the intersection of a semicircular fault with a submeridional disturbance extending along the central part of the field. The formed blocks of the field were re-displaced relative to each other in the post-ore stage during renewed tectonic movements, along which part of the Fedorov-stock was faulted. The ore bodies in the footwalls have a predominantly pyrite composition with an admixture of chalcopyrite. Solid, massive structure of pyrite ores are replaced downwards, through veinlet, veinlet-impregnated ores, by practically barren hydrothermally altered rocks. The pyrite core of the ore bodies is laterally enveloped by copper-zinc ores, especially in the apical part. So two commercial types of ores are distinguished at the field: early pyrite ores and superimposed copper-zinc ores, which are broken in time, but spatially combined by the stage of ore mineralization. The latter was preceded by a stage of intensive metasomatic alteration of the ore-bearing rocks.

Of natural interest is the assumption of multilevel of Gadabay field. The abovementioned is reinforced by the fact that pyrite mineralization is found in the lower volcanogenic strata outside the Gadabay ore field in the samename and other ore regions of the Somkhito-Karabakh island arc (Bitti-Bulag, etc.).

The general morphology and structural peculiarities of the Garadag-Kharkhar group of porphyry copper fields are determined by the Maarif-Garadag ore-controlling fault of the northwestern direction, as well as diagonal ore-conduit faults, to which crushing and shear zones, small zones of eruptive breccias, subvolcanic and hydrothermal formations are confined. The zones of increased fracture adjacent to these faults turned out to be a reservoir of Late Jurassic (Early Cretaceous) stockworks of gold-bearing Cu-Mo-porphyry mineralization.

Alaverdi ore district (Armenia) and its ore-bearing

Copper-bearing stock-like ore bodies are concentrated in the late Bajocian horizons of siltstones and sandstones in the Alaverdi region, and vertical vein-like ones are in rhyodacitic hyaloclastites and effusives of andesite-basalts of the early Bajocian age. Vein bodies are marked by narrow zones of quartz-sericite-chlorite metasomatites. Besides that, the Tekhut copper-porphyry field is located near Alaverdi.

According to the K-Ar method, the age of the Tekhut phaneritic intrusions is Neocomian (133±8 million years). The background (phanerite) igneous rocks, as well as the porphyry bodies, are essentially sodium and high-alumina and belong to the tonalite group (Кекелия и др., 1991, 1993).

According to V.Z.Yaroshevich (Ярошевич, 1985), who studied gas-liquid inclusions, the fluids from which the ore substance precipitated were chloride-sodium-potassium, highly concentrated (50-20 wt% or 30-40 g/kg in terms of NaCl); mineral formation occurred in the range of 400-220°C, the pressure could exceed 100 kbar; sulfide sulfur at the Tekhut field is characterized by a small dispersion of the $\delta^{34}S$ value and is close to the meteoric standard; sulfate sulfur (anhydrite) is heavier relative to sulfide sulfur by 13.5%. The oxygen isotope composition of the water inclusions varies from I3.0 to -4.1%, which may show some dilution of magmatic waters (fluids) by meteoric ones.

The Alaverdi ore region, which covers the extreme southwestern part of the Somkhito-Kafan tectonic zone of the fragment of the paleo-island-arc structure, is composed mainly of Bajocian-Bathonian and Late Jurassic-Early Cretaceous volcanic complexes in its central part. The Alaverdi volcanic structure was formed as a result of at least three powerful phases of volcanic activity (Бабазаде и др., 2015). It is important to emphasize that the differentiation trend of the Early Bajocian volcanites is located in the transition zone between the tholeiitic field and the calc-alkaline band on the AFM diagram (Кекелия и др., 1991, 1993), and the trends of the later Middle Jurassic volcanites are within the calc-alkaline band. According to general geological data, four groups of endogenous fields of non-ferrous metals are distinguished in the region

(Сопко, 1971). It is assumed that the earliest are baryte-polymetallic ores confined to the apical part of the Akhtal intrusion. The Alaverdi copper field was apparently formed in the late Bajocian-Bathonian, and the Shamlugh field in the late Jurassic, since the massive copper-pyrite stocks are screened by late Jurassic rhyodacites here. The recent mineralization of the subduction stage of the development of the paleo-island-arc structure is the abovementioned copper-porphyry Tekhut field, which shows a paragenetic connection with the Early Cretaceous tholeiitic complex (Кекелия и др., 1991, 1993). It follows from the available data (temperatures of homogenization of gas-liquid inclusions in quartz ores (Аревадзе, 1989; Кекелия и др., 1993) that the Alaverdi field was formed at temperatures of 205-280°C, Shamlugh at 185-210°C, and Akhtal at 170±200°C. N_2, CO_2 among the gases in the inclusions, and a small amount of water were observed. High concentrations of SO_4^{2-}, Ca, Na were observed in aqueous extracts from gas-liquid inclusions of ores of the Gafan field, which is an analogue of the Alaverdi field. In addition, significant concentrations of heavy metals were revealed in aqueous extracts, besides common cations (K, Na, Ca, Mg).

The isotopic composition of sulfur of sulfides in the fields of the Gadabay and Alaverdi ore regions is almost close to the composition of meteoric sulfur. Pyrites of the early quartz-pyrite stage of mineral formation are characterized by the value of $\delta^{34}S$=4.9‰, and 1.2-1.5‰ in the chalcopyrite-pyrite-sphalerite stage, which can be explained by the lightening of sulphide sulfur due to the accumulation of ^{34}S in baryte and anhydrite. The sulfur isotope composition of chalcopyrite 2.6‰ and sphalerite 4.2 ‰ and 7.2‰ testifies to the staged formation of the ores of the Gadabay field. The isotopic composition of oxygen in quartz from copper fields of the Gadabay ore region was equal to +8.9-+11.3‰, Mekhmana ore region (Azerbaijan) to +6.9-12.8‰, Paragachay copper-molybdenum field (Daralagoz block, Azerbaijan) to +9.7‰, Alaverdi ore region to +10.3-+0.5‰. Hydrogen of water from fluid inclusions (Alaverdi field) is characterized by 3D values equal to -75±0.5‰. New data on the isotopic ratios of sulfides sulfur and oxygen from quartz taken from fields in the Bolnisi, Gadabay and Alaverdi regions should be added to this. The analyses were carried out in the USGS laboratory (Denver, USA). The homogenization temperatures of gas-liquid inclusions in quartz from epigenetic fields of the Lesser Caucasus were determined in the same laboratory. The homogenization temperatures of liquid inclusions from copper ores were found to be 315-325°C at Madneuli, 295-305°C at the Gadabay gold-copper pyrite field, 300-320°C at the Kapaz and Tulallar gold-pyrite fields (Абдуллаева и др., 2021), 315-335°C at the Tutkhun gold-sulfide field (Azerbaijan) (Babazadeh et al., 2024); 245-250°C at the Akhtala polysulfide field (Armenia), 325-330°C at the Tekhut copper-porphyry fields (Armenia), and 340-345°C at the Garadag-Kharkhar group (Azerbaijan) (Баба-заде и др., 2015).

Oxygen isotope ratios from quartz of copper and copper-porphyry ores of the Madneuli (Georgia), Gadabay, Bitti-Bulag, Gulyatag, Janyatag, Damirli, Garadag-Kharkhar group, Paragachay (Azerbaijan) and Tekhut (Armenia) fields may show the participation of magmatic waters during the ore-forming process (Тейлор, 1982). The sulfur isotope ratios from sulfides are ambiguous at the epigenetic deposits of the Lesser Caucasus island paleoarc, but the authors of this article believe that most of the sulfur had a magmatogenic source. We state here that these data do not contradict the results of thermobarogeochemical studies previously carried out in the laboratory of the Caucasian Institute of Mineral Resources.

Geological and genetic model of gold-bearing volcanogenic fields of non-ferrous metals in paleoisland-arc structures

Volcanogenic fields are concentrated in geological complexes that were formed during the interaction of oceanic and continental plates. This is usually a zone of active continental margins, under which oceanic crust subducts. Active margins at certain stages of geological history were fragmented and are perceived as “accumulations” of microplates.

Back in the 80s of the last century, many scientists (Абрамович, Клушин, 1987; Митчел, Гарсон, 1984; Rona, 1986) emphasized blocks of the Earth’s crust that corresponded (taking into account the principle of actualism) to fragments of both passive and active continental margins. It is possible to recognize geological formations Within the fragments that contain certain ore accumulations. In our case, we are dealing with the Alpine fragments of the Pontic-Lesser Caucasus island arc, which is characterized by both volcanogenic-sedimentary and epithermal fields (epigenetic), known in the literature as the Kuroko type (Франклин и др., 1984). One of them was an ore accumulation environment and acted as either physical or geochemical barriers for the ore-bearing system, while others were considered as a source of ore matter and also as a source of energy supply. These metallogenic categories are intensively used in genetic constructions. The concept of “ore-generating system” is also often used. It should be perceived as a set of interacting elements acting in a given relationship as a whole (Тюхтин, 1988).

The integrity of such systems is determined by their emergence, the so-called cognitive properties. F.A. Letnikov (Летников, 1993) emphasized that geological systems of different levels (The Earth as a whole, the components of its "levels", for example, magmatic and fluid systems) have synergetic or, in other words, self-organizing properties.

The ore process is identified with the development of a high-energy geological system, practically open to its mobile components. The following act as macroelements of dissipative fluid systems: 1) fluid formation areas (there are scientists' controversial and contradictory opinions about them (Чухров, 1976); 2) their movement paths; 3) discharge areas with structures (physical) and geochemical barriers, where the accumulation of ore matter occurs.

This paper proposes a mental-logical model of the development of ore-generating systems and, first of all, that part of it that is responsible for the precipitation and coning of ore components. The model identifies those features-factors that are necessary and sufficient for the conduct of ore-forming processes. In order to substantiate the logic of the provided constructions, besides general geological data, thermobarogeochemical data and isotopic ratios of the leading ore-forming elements are used. It is important to emphasize (Баба-заде, 2000) that the genetic model should be perceived as a kind of abstraction, which takes into account mainly not the external similarity of individuals (deposits, ore bodies), but the standard nature of the processes occurring in the system.

According to geophysical data (Рингвуд, 1981), the root parts of magmatic bodies under island arcs with developed sialic crust are usually located at depths of 60-80 km. Since these depths correspond to the lower crust, researchers (Белоусов, Кривенко, 1983; Рингвуд, 1981; Уилли, 1983) assume a connection between orogenic series magmas and partial melting of amphibolites.

Traces of intensive hydrotherm activity – hydrothermal changes in rocks and ore accumulation are usually observed under the volcanic dome (for example, Madneuli) or above the Chayeli dome. The idea of a magmatic source of fluids in volcanogenic fields has lost its appeal in recent decades due to the difficulties associated with the need to explain the involvement of significant volumes of water during the hydrothermal process. The mechanism of fluid separation is thought to be a relatively short-term phenomenon. "Traces" of the latter in magmatic bodies are expressed by autometasomatic alterations, equal distribution of submicroscopic individuals of oxides and sulfides in silicate crystals or in the intergranular space of rock-forming minerals. The results of isotope-geochemical studies of volcanogenic fields incline researchers to the conclusion on a large content of meteoric waters in hydrosystems (Синяков, 1986). Experiments also show a small content of magma water in hydrosystems, not exceeding 0.0005% of the total mass of water (Гричук и др., 1984).

It is well known that there is a relationship between ore components and their content in ore-bearing rocks (Баранов и др., 1990; Фарфель, 1988). Moreover, hydrothermally altered rocks near ore accumulations are characterized by a deficit of metals. Experimental work (Гричук и др., 1984; Hodgson, Lyndon, 1977) on the extraction of elements from rocks under PT conditions corresponding to the functioning of fluids also confirms the possibility of considering ore-bearing magmatic and sedimentary formations as a source of metals.

Hydrothermal solutions with ore elements are similar in salinity to seawater, and at the same time they are enriched in comparison with seawater by several orders of Fe, Ag, Pb, Cu and Zn (Mottl et al., 1979). The initial redistribution and separation of ore components is associated with the crystallization conditions of magmatic rocks with a specific component composition. Spherical acetates of oxide-ore segregations of liquation nature have been revealed (Прокопцев, Прокопцев, 1990) in the basalts of mid-ocean ridges, and earlier in siliceous formations. Sulfides have also been observed in the form of "drops" in the impregnations of clinopyroxene and feldspar in the ore subalkaline effusives of the rift valley of the mid-ocean ridge (Акимцев, Шарапов, 1993). These ore liquates contain nickel-pyrrhotite, sphalerite, chalcopyrite, silver, albite and potassium feldspar. As some researchers (Нортон, Кэттл, 1982) believe, the further migration path of ore elements in volcanic regions is determined by the involvement of sea and formation meteoric waters in the convective flow due to a decrease in their density under the influence of the thermal anomaly of intrusions introduced into volcanites. Aggressive heated waters acquire the properties and composition of ore-bearing fluids, interacting with intrusions and volcanites.

Large-scale ore genesis, according to materials collected from the World Ocean (Гринберг и др., 1990; Ельянова, Мирлин, 1990; Ельянова, 1999; Рона, 1986), is carried out sequentially during the process of: 1) crystallization of magmas; 2) interaction of surface waters that have acquired "aggressiveness" with volcanites; 3) stable functioning of the physicochemical barrier in the area of hydrotherm discharge (whether it is the seabed or the near-surface zone of the Earth's crust).

Volcanogenic fields of non-ferrous metals are characterized by the following peculiarities:

1. Both sedimentary-hydrothermal and veinlet-impregnated fields are confined to volcano-depressions. The former are confined to their axial zones, the latter occupy the near edge parts and are controlled by extrusive domes. The component composition of the ores depends on the petrochemical characteristics of the ore-bearing volcanites and their comagmates. Baryte-polymetallic mineralization is preferentially associated with sodium-potassium rhyodacites, and copper-zinc (Кривцов, 1989) mineralization is associated with andesite-basalts and sodium rhyolites;

2. The fluids that formed the volcanogenic fields were weak acid sodium chloride, with low salinity (Овчинников, 1988; Синяков, 1986; Франклин и др., 1984; Баба-заде, 1999, 2000). Low salinity of fluids is also characteristic of modern sulfide accumulation in the World Ocean (Бортников и др., 2004; Бортников, Викентьев, 2005). However, brines (up to 30 mol% - equiv. NaCl at a temperature of 200-400°C) have also been observed for some fields of sulfide formation (Бортников, Викентьев, 2005). Data on the Lesser Caucasus fields do not contradict this (Баба-заде и др., 1990; Баба-заде, 1999, 2000; Кекелия и др. 1991; 1993).

It is shown in the work (Yardley, Bruce, 2005), which summarizes the data on crustal fluids, that temperature is one of the main factors affecting the concentration of metals in the solution. Metals Fe, Mn, Zn, Pb in solution are most likely in chloride complexes. For example, for zinc $ZnCl^{+}$ and $Zn\ Cl^{2-}{}_4$ (Seward, 1984). The concentration of the abovementioned metals also increases with the chloride concentration. Metals are most likely concentrated in brines – in evaporites, from which Pb-Zn fields of the Mississippi-Missouri type are formed.

According to researchers (Франклин и др., 1984), the maximum temperatures of ore deposition are comparable to the boiling temperatures of the solution. The “base” of hydrotherm evaporation with temperatures over 270°C is located at depths of 300-400 m in areas of modern volcanism (Синяков, 1986).

According to the data on the Lesser Caucasus region, the maximum homogenization temperatures at copper fields were equal to 410-390°C, and at baryte-sulfide fields ~280°C (Ярошевич, 1985). According to our data, the maximum fluid pressures at epigenetic fields of nonferrous metals in the Lesser Caucasus, as well as the diagrams (Shepherd et al., 1985) used to determine the pressure approached 150-200 bar, and mineral formation occurred at depths of 400-600 m from the paleosurfaces.

3. The known data on the isotopic composition of hydrogen and oxygen of fluid inclusions in quartz, baryte and calcite of volcanogenic baryte-polymetallic ores were previously interpreted in favor of a high content of meteoric water participation during the ore-forming process. Meteoric water could be inferior to magmatogenic water for copper ores (Кривцов и др., 1987; Франклин и др., 1984; Ярошевич, 1985).

The results we obtained for determining oxygen isotopes in the laboratory of the US Geological Survey (Denver) also do not contradict these data.

4. The data on the isotopic composition of sulfur in sulfides and sulfates, as already mentioned, are ambiguous: the isotopic composition of sulfur in sulfides approaches the composition of meteoric sulfur, and sulfates are heavier by 14±3‰.

5. Boiling of fluid at most fields with hydrothermal-sedimentary deposits did not occur at all or possibly, occurred before the thermals reached the seabed, thereby facilitating the preparation of ore-conduit systems. The most favorable conditions for the stable accumulation of hydrothermal-sedimentary ores were created at the bottom of sea basins, the depths of which varied within 2-3 km (Бортников, Викентьев, 2005; Stackelberg, 1985).

It should be stated that according to the modern data, the hydrothermal-sedimentary deposits formed due to the “black smokers” were formed following the completion of the accumulation of andesite-dacite-rhyolite complexes (deposits, as result from observations at fields of Kuroko-type, are located on rhyodacites domes). The mineral zoning that we see in hydrothermal-sedimentary deposits is explained by the redistribution of ore-forming components as a result of the destruction of “hills” and their diffusion from lower to upper levels during the process of “washing out” of ores by fluids (Hannigton et. al, 1986). An example is the modern ore structure in the Pacific Ocean, on the Explorator Ridge, where high-temperature sulfides underlie layers of lower-temperature Fe-Mn sulfides, baryte and silica. According to G.D.Grichuk (Гричук, 1999), the anhydrite-pyrite structure (they proposed a thermodynamic model) is eventually replaced by a later silica-sulfide substance. The occurrence of anhydrite in the “ore mounds” is explained by the involvement of sea waters in the discharge zones. Seawater is heated, resulting in anhydrite deposition (Черкашев и др., 1999).

The levels of mineral formation in epigenetic fields are generally comparable to the zones of “black smoker” pipes, the boundary anomalous physicochemical parameters of which caused the simultaneous crystallization of anhydrite and iron sulfides. These conditions correspond to zones of hydrosystems with minimum activities >PO_2, coinciding with the lower boundary of the baryte stability field at equal activities of H_2S – SO_4^{-2} (Франклин и др., 1984). The zonal distribution of metals in baryte-sulfide deposits can be explained by: 1) different stability of complex compounds (Овчинников, 1988; Франклин и др., 1984); 2) greater dependence of the solubility of copper minerals on temperature compared to the solubility of sphalerite and galena (Франклин и др., 1984); 3) dependence of metal deposition on concentration of S^{-2}. Higher concentrations of H_2S are required for precipitation of copper and zinc than for lead at equal concentrations of metals in the solution; 4) action of the hydrosulfuric barrier, the effectiveness of which is determined by low concentrations of S^{-2} (Крайнов и др., 1988).

It can also be assumed that $\sum S$ is sufficient for copper precipitation in fluid discharge zones, while lead, zinc and silver tend to pass the hydrosulfuric barrier with a alteration in ligand. Excess anion precipitator (a known phenomenon in analytical chemistry) acts as a solvent for the complexing agent.

Ch.Heinrich (Heinrich, 2005) stated that magmatic waters with low salinity are able to transport gold under high temperature conditions. His conclusion is based on physical and chemical studies. One of the main conditions is a sufficient amount of H_2S, which acts as a ligand (bisulfate complex). C. Heinrich's paper (Heinrich, 2005) deals with Au-Cu porphyry fields, but, in our opinion, the results of this author's research can also be used in the case of gold-bearing fields such as Madneuli, Dagkesaman, Tulallar, Chovdar, etc.

Conclusions

It can be concluded that ore fields of paleo-island-arc structures, in particular the Pontic-Lesser Caucasus arc, should be expected in the following geological settings: in vents and on the slopes of paleovolcanoes located in volcanodepressions: ore bodies in siliceous parts of volcanogenic-sedimentary strata or above them (in the case of hydrothermal-sedimentary deposits); as a rule, the ores are covered by basic volcanites, but there may be exceptions.

The ores of the Lesser Caucasus fields are clearly epigenetic: veinlet-impregnated and vein mineralization is superimposed on hyaloclastites and tuffites in the Gadabay and Alaverdi ore regions; veinlet-impregnated copper mineralization is occurred in silicified tuffites in Bolnisi, as well as impregnated gold and baryte-sulfide in the form of veins and flat deposits - in secondary quartzites. The ores of the Chayeli fields are similar to the "ore hills" of modern mid-ocean ridges and rifting zones of marginal seas.

Ore bodies in the Gadabay and Alaverdi ore regions are located in a cover of narrow zones of quartz-sericite-chlorite metasomatites; a vertical metasomatic column is occurred in the Bolnisi region: secondary quartzites in the upper part (near-surface solfataric alterations), and higher-temperature silicification in the lower part (quartz-chlorite-sulfide metasomatites with minor amounts of sericite). Ore metasomatites are surrounded by a cover of propylites. Veinlet-impregnated "yellow" ores are surrounded by quartz-hydromicaceous metasomatites at the fields of the Chayeli (Madenkoy) type, under hydrothermal-sedimentary deposits, in the underlying dacites against the background of regional propylites. The latter mark the paths of hydrothermal solutions moving to the marine paleo-ocean.

Stocks and thin lens-veins (group of northern lenses in Gadabay) of copper ores are found in the Gadabay and Alaverdi ore regions; large-volume copper stockworks are predominantly occurred in the Bolnisi region; besides stockworks, thick deposits of lens-shaped massive sulphide ores consisting mainly of pyrite, chalcopyrite and sphalerite in the Eastern Pontides.

It is clear that these differences are due to the different geodynamic regimes of development of individual blocks of the Earth's crust of the paleoisland-arc structure.

Thermobarogeochemical studies have shown that the main copper and gold fields as one of the main sub-ore components of the ores were formed in similar PTX conditions and belong to a single genetic volcanogenic class of fields, despite the difference in the mechanism of ore deposition.

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ЗОЛОТОСОДЕРЖАЩИЕ ВУЛКАНОГЕННЫЕ МЕСТОРОЖДЕНИЯ ЦВЕТНЫХ МЕТАЛЛОВ МАЛОГО КАВКАЗА И ВОСТОЧНЫХ ПОНТИД И ИХ ГЕНЕЗИС

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Резюме. В странах Южного Кавказа и Турции наиболее представительные золотосодержащие вулканогенные месторождения известны в толщах, слагающих фрагменты Понтийско-Южнокавказской палеодуги, активно функционировавшей в течение мезозойского времени. В это время под дугу, которая являясь краевой частью Евразийского континента, субдуцировалась океаническая кора. Отдельные сегменты дуги различались своим геодинамическим развитием, в связи с чем в них возникали разнотипные вулканогенные месторождения. На западе, в пределах Понтид (Турция), помимо эпигенетических, известны и гидротермально-осадочные залежи. Примером последних может служить месторождение Чаели (Маденкой).

В статье вкратце охарактеризованы геологические обстановки нахождения месторождений Турции, Азербайджана, Армении и Грузии. Большинство из них могут быть отнесены к типу Куроко и отличаются характером накопления руд: в Турции известны медно-цинковые залежи, сформированные, по-видимому, в условиях глубоководного бассейна, а восточнее – мы имеем примеры лишь эпигенетических месторождений. Кроме того, в Болнисском районе разрабатывается Маднеульское месторождение, которое являет собой пример полиформационного месторождения и поэтому уникально.

Гядабейский и Алавердский рудные районы, интересны тем, что в них в юрских вулканодепрессиях сосредоточены медные, медно-цинковые и барит-сульфидные руды, а в приподнятых клиновидных блоках, ограничивающих вулканодепрессии, известны медно-порфировые месторождения – Карадагское и Тутхунское. Все месторождения Гядабейского и Алавердского рудных районов, включая медно-порфировые, являются промышленно значимыми.

На базе собранного литературного материала, который накапливался в течение ряда лет, а также собственных данных, была создана мысленная логическая геолого-генетическая модель вулканогенных месторождений.

Месторождения вулканогенной природы, несмотря на то что формируются в сходных PTX-условиях, имеют свой «облик», учет которого крайне важен при прогнозировании месторождений в конкретных районах.

Ключевые слова: *месторождение, рудный район, палеодуга, включение, флюид, изотоп.*

KİÇİK QAFQAZIN VƏ ŞƏRQİ PONTİDLƏRİN ƏLVAN METALLARININ QIZILSAXLAYAN VULKANOGEN YATAQLARI VƏ ONLARIN GENEZİSİ

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Xülasə. Cənubi Qafqazda, o cümlədən Türkiyədə, mezozoy erasında aktiv olan Pontid-Cənubi Qafqaz paleoqövsünün fraqmentlərini təşkil edən təbəqələrdə qızılsaxlayan vulkanogen yataqlar müəyyən edilmişdir. Həmin dövrlərdə okean qabığı Avrasiya materikinin marjinal hissəsi olan qövsün altına gömülmüşdür. Qövsün ayrı-ayrı seqmentləri geodinamik inkişafı ilə fərqlənirdi, buna görə də onlarda müxtəlif tipli vulkanogen yataqlar yaranmışdır. Qərbdə, Pontidlər (Türkiyə) daxilində, epigenetik yataqlardan başqa hidrotermal-çökmə yataqları da mövcuddur. Sonunculara misal olaraq Çayeli yatağını (Madenköy) göstərmək olar.

Məqalədə qısaca olaraq yataqların Türkiyə, Azərbaycan, Ermənistan və Gürcüstanda yaranmasının geoloji mühitindən bəhs edilir. Onların böyük əksəriyyəti Kuroko tipinə aid edilə bilər və filizliliyin zənginliyinə görə fərqlənirlər: Türkiyədə, çox guman ki, dərin sulu hövzədə formalaşmış mis-sink kütlələri formalaşmışdır, şərqdə isə bir yalnız epigenetic yataqları görürük. Bundan başqa Bolnisi rayonunda istismar olunan Madneuli yatağının poliformasion tipə malik olmasını qəbul etməliyik və bu səbəbdən unikaldır.

Gədəbəy və Allahverdi filiz rayonları onunla maraq doğurar ki, burada yuranın vulkanodepressiyalarında mis, mis-sink və barit-sulfid filizlərin cəmləşmişlər, vulkan depresiyalarını məhdudlaşdıran yuxarı qalxmış paz şəkilli bloklarda isə mis-porfir yataqları – Qaradağ və Texut – məlumdur. Gədəbəy və Allahverdi filiz rayonlarının məlum yataqları, o cümlədən mis-porfir yataqları, sənaye əhəmiyyətlidirlər.

On illərlə toplanılan fond materialları, eləcə də aparılmış tədqiqatlarımız əsasında vulkanogen sahələrin mental məntiqi geoloji-genetik modeli yaradılmışdır.

Vulkanogen mənşəli yataqlar, oxşar geoloji şəraitdə əmələ gəlmələrinə baxmayaraq, özünə məxsus olan xüsusiyyətlərə malikdir, bu isə konkret rayonlarda yataqların proqnozlaşdırılması zamanı nəzərə alınmalıdır.

Açar sözlər: *yataq, filiz rayonu, paleoqövs, daxilolma, flüid, izotop*