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*Geology*

# Geological Setting and Genetic Model of the Zopkhito Prospect (Southern Slope of the Greater Caucasus, Georgia)

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**ABSTRACT. In the paper some deposits having similarities with Zopkhito type of deposits are introduced. They are distinguished by low gold grades (2-6g/t) and in some cases are considered to be as "giant" deposits (e.g. Muruntau deposit in Uzbekistan) in terms of ore volumes. Some common insights into the ore deposits formation conditions in carbon-bearing series are presented as well. The gold manifestations have different geotectonic position at the southern slope of the Greater Caucasus. The north extreme manifestations, represented by quarts-arsenic sulfide type, associated with Neogenic zone of tectonic-magmatic activization and are localized in the Lower Jurassic sandy-argilaceous deposits. Zopkhito potential mineral deposit reveals affinity with other hosted by carbon-bearing series deposits worldwide by mineral composition of the ore, as well as by physical-chemical parameters of the ore precipitation. Formation of these deposits at 3-1.5 km depth is well-established fact. The authors suppose that the primary source of gold geochemical anomaly was located in the lower part of the Lower Jurassic rock packages at the southern slope of the Greater Caucasus or even deeper, in the similar to the Dizi series Paleozoic formations. It should be noted that the geological-genetic model is an important instrument used by researchers for the prognosis of some ore deposits. It is summarized that gold accumulation is contributed by the following succession of events: 1) disintegration of the gold-bearing basite-ultrabasite rock-complexes; 2) leaching of gold and other metals from the rock-forming minerals; 3) metals transportation to the flysch type depositional environments; 4) distribution of metals as a result of epigenetic processes; 5) the enrichment of sulfide and porous water by gold during the metamorphism reinforcement. The authors also note that during the shock decompression the volume of melt sharply increases– substance emission takes place as the silicate and fluid-gas phases with concurrent emission of gold-bearing mobilizate (in the nature this processes expressed in the formation of quartz and quartz-feldspar veins). The recognition – visualization of such paleo-processes in the nature will facilitate to exploration conduction, which will eventually lead us to the discovery of a gold deposit.** *© 2017 Bull. Georg. Natl. Acad. Sci.*

**Key words:** ore deposit, gold, geological-genetic model, metal

Hosted by carbon-bearing sedimentary rocks gold ore strata are attributed to the low metal grade (2-6 g/t) mineralized objects, among which are so called giant deposits (with gold reserves 1000 t and more) Muruntau and Sukhoi-log, as well as large deposits (with reserves of several hundred tones) of Olimpiada, Bendito etc. [1]. Gold sulfide disseminated ores are characteristic for the following deposits: Sukhoi-Log, Olimpiada, Kuchus, Kumtori and Bakirchin (CIS), Chuno (USA), and for gold-quartz-low-sulfidation ores - for the Muruntau and Sovetskoe, Nejdaninskoe, Natalinskoe (CIS), Mother-Lode (USA), Bendigo (Australia), Ashanti (Ghana) deposits. The majorities of the ore deposits is of mesothermal origin and are classified as “orogenic gold” deposits [2,3] localized in the accretionary structures of the continental margins.

The generalization of existing material [4] related to the gold – bearing capacities of the carbon-bearing shales exposed that some researchers consider black shales as a source of the ore substance, while others believe, that they serve as a favorable environment for ore deposition or a structural-physical barrier. There is an opinion that gold could be sourced from granitization zones as well. Gold deposits are localized in those rock types, which were initially enriched in gold and organic matter. According to [5], the formation of gold deposits is related to affected by metamorphic processes in terrigenous sediments. According to the concept of N. Kurbanov and N. Fogelman’s (1996) [6] formation of gold deposits hosted by terrigenous strata is possible by the functioning of the exogenous-endogenous or plutogenous energetic systems. Minor magmatic bodies - quartz monzonites, sienites, gabroids and lamprophyres are the essential elements of gold ore fields. Orogenic (or collisional) stage of geodynamic development is the most substantional formation stage of gold deposits, when the giant blocks of the earth’s crust are strongly affected by endogenous processes. Generation of gold –bearing mobilization silicate-fluid system conditioned by partial melting of metavolcanic - terrigenous sediments in PT conditions of amphibolite facies, is in turns the most important stage on the way of gold migration.

## Geological Setting of the Zopkhito Deposit

On the Southern slope of The Greater Caucasus two main ore districts are distinguished: Mestia-Racha and Svaneti. According to the tectonic map of Georgia Mestia-Racha ore district in the geological part occupies the Alpine marginal sea complex [7]. But in present day structure it is part of the fold system of the southern slope of the Greater Caucasus. Its southern part consists of weakly metamorphosed Paleozoic rocks of so-called Dizi series. Central part is composed by Lower-Middle Jurassic sandy-argiliceous rocks of the Kazbegi-Lagidekhi zone and the northern part-of Upper Jurassic-Cretaceous flyish deposits of the Mestia-Tianeti zone [8]. Mestia-Racha ore district, along the so-called “Main thrust of the Greater Caucasus”, is bordered by the pre-Jurassic crystalline basement of the Greater Caucasus. In the Caucasus gold ore paleosystems are established in the megastructures experienced intense tectonic stress in particularities are in allochthons and sutures of the Southern Slope of the Greater Caucasus. Gold occurrences occupy various geotectonic positions on the Southern Slope. The extreme northern occurrences of quartz-arsenic-sulfide type gold mineralization are related to the exposure areas of Neogene tectonio-magmatic activization and are localized in the Lower Jurassic sandy-argillaceous deposits. Accumulation of the latter, as it was already mentioned, took place in the axial parts of the marginal sea basins. Ore bearing clay-shale-sandy strata is carbon-bearing and weakly carbonaceous. Here 2-3 meters thick gold-bearing zones with gold grades 4,5-7 g/t (Zopkhito deposit) is represented by rich in pyrite and arsenical pyrite silicified carbon-bearing clay shales. They are characterized by significant extend (hundreds of meters along the strike and 200-300 m. along the dip) and comprise thin, abrupt quartz-antimonite veins. Some of these veins are tungsten-bearing. Ore hosting carbon-bearing shales are enriched in cobalt, lithium, vanadium, arsenic and zinc; diagenetic pyrites are often gold-bearing. Apparently, the Zopkhito block formation is the result of the Main Thrust fracture system's complication.

## The Possible Way of Formation and Development of Gold Bearing Systems

Zopkhito ore deposit has much in common with many deposits hosted by the carbon-bearing terrigenous strata worldwide expressed both in mineral composition, and in physical-chemical parameters of ore precipitation[9,10]. Therefore during the creation of genetic model of deposits general characteristic for most of ore-bearing objects features have been taken into account, in particular: 1) concentration of gold (deposit formation) in the Earth's crust is as follows: initially gold is "released" from one mineral phase (from the primary gold concentrator) and then it is transported as a solution to the ore precipitation place. 2) basite-ultrabasite footwall complexes in the region are intended to be the possible primary sources for gold bearing allochthonous plates 3) during the gold migration towards its concentration place the most important stage is the period of exogenous disintegration of gold-bearing rocks.

The gold-bearing fluid systems operated at the abyssal depths (5-10 km) though were developing in the upper levels as well (3-1.5 km). Ore precipitation was preceded by the process of "gold-bearing mobilization" isolation. During the transformation into greenshist and amphibolites facies (PT conditions) the "purifying" of the rocks from heavy metals took place. 4) Racha deposits' syngenetic pyrites, together with the geological features, don't exclude involvement of volcanic activity in the formation of ore-bearing areas. 5) The Zopkhito deposit was formed as a result of the functioning of the$H_2O$-$CO_2$-$CH_4$ hydrosystem. Salinity features of the composition varied from the bicarbonate – sodium (monoquartz paragenesis) to the bicarbonate-sodium- calcium-manganese (quartz-antimonite association). The quartz-pyrite-arsenopyrite paragenesis was formed at the 325-295±10$^0$C temperature. The later stage quartz-anthimonite paragenesis was formed at the 225±10$^0$C temperature and under the minimum pressure (0.5 kbar) conditions. According to the above mentioned parameters it is possible to make correlations between the Rachadeposits and Charmitani ore deposit from Uzbekistan, where the formation of quartz-arsenopyrite paragenesis took place at 360-270$^0$C temperature and at the 2.7-0.8 kbar pressure, during the low activity of the oxygen ($10^{-27}$– $10^{-37}$bar) and sulfur ($10^{-8}$–$10^{-20}$bar) [11]. Quartz-arsenopyrite paragenesis on the "Olimpiada" ore deposit in Russia was formed at a temperature range of 380-280$^0$C interval and the antimonite-berthierite – in 280-220$^0$ temperature interval. At the same time during the ore formation process the pressure variated within 1.4-0.6 kbar.

Formation of Zopkhito style deposits was preceded by the sustained formation period of the syngenetic gold anomalies of the ore bearing stratum. Apparently the first anomaly was located in the lower part of the Lower Jurassic suite at the Southern slope of the Greater Caucasus or deeper – in the Paleozoic metamorphic formations of Dizi series. Summarizing previously published available material of [12] concluded that organic material from the terrigenous strata serves as favorable reduction environment for the precipitation of metals. The anomalies in some cases might have formed earlier than the ore bearing suites at the expense of basitic metamorphic formations' disintegration. It should be also recognized, that unfortunately the problem of the initial source of the metals in the primary anomalies still remains undecided. On the example of the Georgian (Racha) deposits one could imagine following course of events: as a result of intensive tectonic tension during the collision – post-collision period on the boundary of crystalline basement of the Greater Mestia-Racha geoblocks formation of tectonically weak structure took place. This was the area favorable for the Neogene granodyoriteporphyry, sienite-porphyry and lamprophyre dykes' invasion and for the formation of the fracture zones which "absorbed" the gold bearing mobilizates due to pressure drop. In the literature was mentioned [13] that the fluids, represented by mixture of $CO_2$, $CH_4$, $H_2S$, $N_2$, are characteristic for the mezothermal deposits, such as: Nejdaninskoe and deposits from Racha. Buryak(1986) emphasized [14], that trapped in the gas-fluid inclusions of the mezothermal deposits - $CO_2$, $CH_4$, $H_2S$, $N_2$, $NH_3$, $CO_2$, $H_2$, are the results of the organic C thermal disintegration and dissociation of carbonates during the hightemperature metamorphism. At the ore deposition level (abyssal-hypabyssal level – 3-3.5km) siliceous-fluid mobilizate split into silica gel (crystallized infill of fractures) and water-gas mixture. Interaction of the latter with quartz-veins hosting rocks was finally expressed of intense silicificatin and sulphidization.

## Conclusions

It is well known that processes favorable for the ore matter dispersion are predominant in the Earth's history and only in some special cases part of them is responsible for generation of substantial ore minerals concentrations in the Earth's crust. In case of gold the following consistent processes answer these conditions: exogenic disintegration of the gold bearing basite-ultrabasite complex; the (leaching) of metals from minerals; their transportation into the flyschoid accumulation areas ("sizure" by clay minerals or organic matter); distribution of the metals as a result of epigenetic process (part of metals is accumulated in the diagenetic sulfides, another part is dissolved in the porous water); the enrichment of sulfide and porous water by gold during the metamorphism intensification; partial melting of gold- bearing metaterrigenous and metavolcanic rocks under the influence of the heat energy of mantle diapirs, upward migration of the local magmatic chambers and further decompression influenced magma melting. According to [15], the granitic magma is near-equilibrium at the level of its formation (PT conditions of amphibolites facies), because in isolated conditions the temperature of the melt is close to the surrounding temperature. During the gentle decompression (isothermal conditions) mechanism of melt structuring and liquation spherulites(as well as of schlieren pegmatites and miaroles) becomes active. During the shock decompression, when the system abruptly occupies higher levels (T- $850^0$C, P-1-2 kbar), the volume of the melt sharply increases – the homogeneous substance is divided into siliceous and fluid - gas phases. At the level of "shock" decompression (hipabyssal level) "fluid phase" – gold-bearing mobilizate is distinguished. Its oxygen-bearing part is defined in nature as a quartz and quartz-feldspar veins, and the interacted with carbon-bearing terrigenous rocks gas-water phase- as hydrothermal metasomatites (berezites) and disseminated sulfide mineralization.The recognition such paleo - processes in the nature is very important in exploration aiming the discovery of gold deposits.

*გეოლოგია*

# ზოფხიტოს ოქროს საბადოს გეოლოგიური პოზიცია და გენეტური მოდელი (კავკასიონის სამხრეთი ფერდობი, საქართველო)

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**სტატიის შესავალში აღწერილია საბადოები, რომლებიც ავლენენ მსგავსებას ზოფხიტოს ტიპთან. საბადოები გამოირჩევა ოქროს შედარებით დაბალი შემცველობებით (2-6 გ/ტ) და ზოგიერთ შემთხვევაში წარმოადგენს ,,გიგანტებს“ მადნის მოცულობის თვალსაზრისით, ასეთია მაგალითად უზბეკეთის ოქროს საბადო ,,მურუნტაუ“. მოყვანილია ზოგადი წარმოდგენები საბადოების ფორმირების პირობებზე ნახშირბადიან წყებებში. ოქროს გამოვლინებები კავკასიონის სამხრეთ ფერდზე სხვადასხვა გეოტექტონიკურ პოზიციებს იკავებს. უკიდურესი ჩრდილოური გამოვლინებები, რომლებიც მიეკუთვნება ოქროს გამადნების კვარც-დარიშხან-სულფიდურ ტიპს, უკავშირდება ნეოგენურ ტექტონო-მაგმატური აქტივიზაციის გამოვლენის არეებს და ლოკალიზებულია ქვედაიურულ ქვიშიან-თიხიან ნალექებში. ზოფხიტოს ოქროს პოტენციური საბადო ავლენს მსგავსებას მსოფლიოს სხვა საბადოებთან ნახშირბადიან წყებებში, როგორც მადნების მინერალური შემადგენლობით, ასევე მადანდალექქვის ფიზიკურ-ქიმიური პარამეტრებით. დამტკიცებულია, რომ საბადოები ჩამოყალიბდა 3-1,5 კმ სიღრმეზე. ავტორები ვარაუდობენ, რომ ოქროს პირველადი გეოქიმიური ანომალიის წყარო იყო განლაგებული კავკასიონის სამხრეთი ფერდობის ქვედაიურული წყების ქვედა ნაწილში ან უფრო ღრმად, ,,დიზის“ წყების მსგავს, პალეოზოურ წარმონაქმნებში. აღსანიშნავია, რომ გეოლოგიურ-გენეტური მოდელი წარმოადგენს აუცილებელ ,,ინსტრუმენტს“ რომელსაც იყენებენ მკვლევარები ამა თუ იმ საბადოების პროგნოზირებისათვის. შეიძლება დავასკვნათ, რომ ოქროს დაგროვებას ხელს უწყობს შემდეგი თანმიმდევრული მოვლენები: 1) ოქროსშემცველი ბაზიტ-ულტრაბაზიტების დაშლა; 2) ლითონების (პირველ რიგში ოქროსი), ,,გამოტუტვა“ ქანთმაშენი მინერალებიდან; 3) ლითონების გადატანა ფლიშოიდური ნალექების დაგროვების ადგილებში; 4) ლითონების გადანაწილება ეპიგენეტური პროცესების შემოქმედების შედეგად; 5) მეტამორფიზმის გაძლიერებისას სულფიდების და ფოროვანი წყლების ოქროთი გამდიდრების პროცესი. ავტორები აღნიშნავენ აგრეთვე, რომ ,,შოკური“ დეკომპრესიის დროს მკვეთრად იზრდება მდნარის მოცულობა - ხდება ნივთიერების გამოყოფა სილიკატურ და ფლუიდურ-გაზურ ფაზებად. ამ დროს, ალბათ, გამოიყოფა ოქროსმატარებელი მობილიზატი (ბუნებაში პროცესი გამოხატულია კვარციანი და კვარც-მინდვრისშპატიანი ძარღვების ჩამოყალიბებით). ზემოთ აღნიშნული პალეოპროცესების დაფიქსირება ,,დანახვა“ ბუნებაში ხელს შეუწყობს ძებნითი სამუშაოების ჩატარებას, რაც, ჩვენი აზრით, დაგვირგვინდება ოქროს საბადოს აღმოჩენით.**

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