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Geology

Ore Occurences in the Georgian Segment of the Eastern Greater Caucasus: New Research Results

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(Presented by Academy Member David Shengelia)

ABSTRACT. After almost 30-year suspension of metalogenic research in the Georgian segment of the Eastern Greater Caucasus (within Tusheti and Kakheti regions) the authors were able to carry out a new geological prospecting work in the region. The already known ore occurrences of Tebulo, Ilurta, Satskhvre-khorkhi, Abano, Quachadala, Artana, Loduani, Chelti, Sharokhevi and Areshi were studied. At the same time, some new and very interesting ore occurences were discovered in the hydrothermally altered zone of the r. Stori (Gelia, Bendena and the zone enriched with Th) and pyrite-polymetallic ore occurence near the village Lechuri. The latter should be of great interest, since it shows lots of similarities to Philizchay pyrite-polymetallic deposit by its geodynamic position and mineralogical-geochemical parameters, which makes necessary further detailed study of the above-mentioned ore. In addition, elevated concentrations of gold were detected for the first time in the region. Among them Tebulo ore field is worth noting, where elevated concentrations of gold were defined in both pyrite-polymetallic ores and silicified zones, which should be considered as one of the important results of our study. Moreover, the studied ore occurrences are characterized by concentrations of such important elements for modern high-tech industry as thorium, bismuth, cobalt and cadmium. Chemical analysis of samples were carried out with a ICP-MS device using different methods at AlxChemex laboratory of Vancouver (Canada), at chemical laboratories of the National University of Taiwan and "CMG" Ltd (Georgia). *© 2015 Bull. Georg. Natl. Acad. Sci.*

Key words: *Eastern Caucasus, Georgia, ore occurences, new research.*

Introduction

In recent ten years, the overall price of industrial and precious metals has been increasing at the world market due to the rapid growth of industrialization and urbanization of the world population. This is a clear indication that it is necessary to speed up the search of new mineral deposits and, at the same time, to reevaluate the potential of already discovered deposits in accordance with the present market requirements and mining technological capabilities.

Taking into consideration these challenges the authors decided to study the known ore occurences and reveal new possible mineralized areas in the

Tusheti and Kakheti regions of the Georgian segment of the eastern Greater Caucasus. The interest in research of the ore occurrences in the region was intensified by the fact that in the 1960s in the neighboring Azerbaijan (southern slope of the Greater Caucasus), in the same geological settings some significant copper-polymetallic deposits were found: Katsdag, Philizchay and Katekh, and in the north Caucasus - deposit of Kizil- Dere (Dagestan). It should be noted that in 1970s and 1980s a large-scale geological exploration of nonferrous metals was carried out within the Kakheti region of the Greater Caucasus, which did not have a great success.

In the Georgian segment of the Eastern Greater Caucasus (within Tusheti and Kakheti regions) the authors were able to carry out a new geological prospecting work in the region, which resulted in important novelties after almost 30 year suspension of metalogenic research.

The present publication is a part of that research.

Materials and Methods

During the geological field works over 200 petrographic samples, about 700 geochemical samples and 12 samples of magmatic rocks for isotopic dating were taken. Geochemical samples weighing 3-4 kg were taken using single point method and the samples for isotopic dating weighed 6-7 kg. All samples were collected and dotted on the topographic map using GPS. Silicate analysis, petrographic and mineragraphic description of rocks were carried out at the geological laboratory of I. Javakhishvili Tbilisi State University. Isotopic dating of zircons (U-Pb method) and analysis of rare element concentrations in some samples were made at the laboratory of Geology Department of Taiwan National University. Geochemical analysis on metal content in samples were conducted at AcmeLab Vancouver laboratory with the ISP-MS equipment by different methods, and also at the chemical laboratory of "RMG Gold" Ltd - by the atomic absorption spectrometry method.

Brief geological Description of the Region

The Caucasus represents a phanerozoic orogenic unit formed between the Euro-Asian south continental margin and Arabian plate. It stretches 1200 km between the Black and Caspian seas. The Greater Caucasus is the northernmost terrane of the Caucasus orogen, which is accreted on the southern margin of the Eurasian continent. It is currently a folded-thrust formation, in which two major structural stages are distinguished: a pre-Mesosoic crystalline basement and Meso-Cenozoic sedimentary and volcanic-sedimentary cover [1, 2].

The Georgian segment of the Eastern Greater Caucasus, with 40-25 km width, can be traced for about 125 km to east from the Iori-Alazani watershed till the r. Mazimchay valley (Azerbaijan border). Its northern border runs along the boundaries of Dagestan and Chechnya, and to the south it is separated from the r. Alazani depression by the regional fault and covers approximately 3900 km^2 area.

The research area on the southern slope of the Greater Caucasus is outcropped by the Alazani River sources and its left tributaries: rr. Makhvali, Stori, Didi Khevi, Lopota, Chelti and others (Kakheti region), and on the northern slope it is outcropped by the River Alazani of Tusheti and its tributaries (Tusheti region). The sedimentary covers of both segments are approximately similar and mainly represented by intensively folded Lower-Middle Jurassic terrigenous schists, shales and sandstones [3], and dacite-andesite-basaltic layers and tuffs are subordinated [4]. In the Middle Jurassic, this sedimentary cover was intersected by numerous magmatic bodies of different composition and thickness. The whole complex of rocks underwent intensive crush, brecciation, hydrothermal alteration and ore mineralization.

Ore Occurences

The research of ore occurrences in the eastern Greater Caucasus Georgian segment has a long history. As early as the beginning of the last century

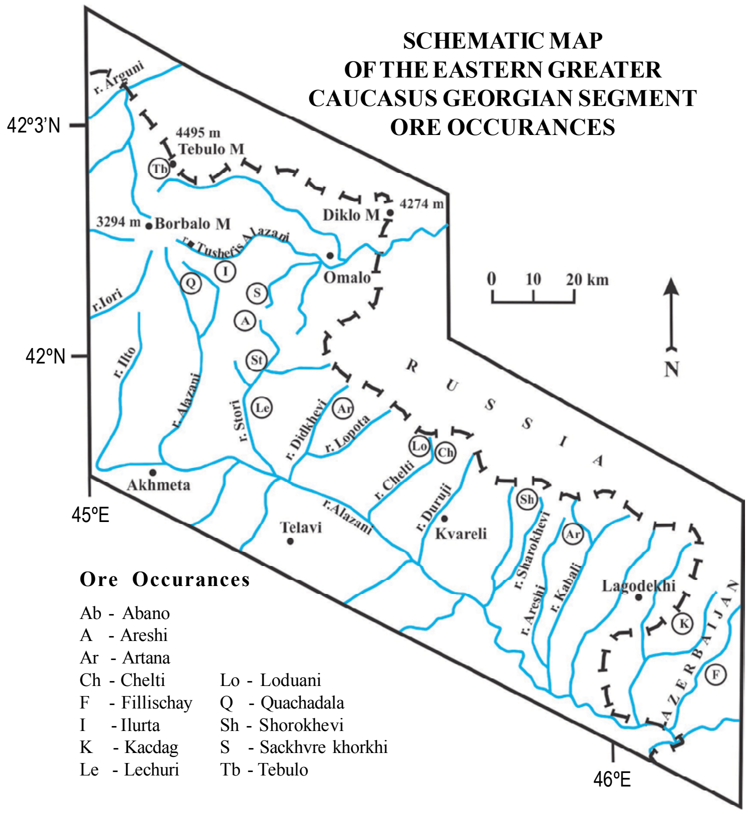

Fig. 1. Schematic map of main ore occurences in the Georgian Segment of the Eastern Greater Caucasus.

V. G. Yudovski, a mining engineer of the Russian Emperor, worked in Tusheti region and considered the Tebulo ore manifestation as one of the major mineralizations in the Caucasus. According to him, Shamil carried ore from Tebulo to Dagestan for weapon production. In 1910-1918 British geologists working in the eastern Greater Caucasus Kakheti region, at the sources of the r. Didi Khevi, exported copper ore to England. In the past century G. Kharashvili studied the Kakheti ore manifestations [5]. Later in the 1970s, the government launched special exploration works for copper-polymetallic mineralization [6, 7], which did not report significant practical results.

Nowadays over 100 copper-pyrrhotite and pyrite-polymetallic ore occurrences of different scales are met in the eastern Georgian segment of the Greater Caucasus, which form impregnations, lodes, veinlets or massive ore bodies at the present erosion level (Fig. 1). Here mainly impregnations and veins are formed, which sometimes turn into massive ores.

Ore mineralization is preceded by hydrothermal alteration and silicification of rocks, during which quartz-sericite-pyritic, quartz-sericite-chlorite-pyritic, albite-epidote-chlorite-carbonate-pyritic associations are formed. In the later crack systems of these rocks quartz-pyrite-pyrrhotitic, quartz-chalcopyritic – and, at the end, quartz-calcite-polymetallic associations crystallize from hydrotherms (Fig. 2).

We studied the known ore occurrences of Tebulo, Ilurta, Satskhvre Khorkhi, Abano, Quachadala, Artana, Loduani, Chelti, Shorokhevi and Areshi. Besides the above-noted, some ore manifestations were observed and studied for the first time, in particular, in the limits of the hydrothermally altered zone of r. Stori (Gelia, Bendena and zone enriched with Th) and also at the village Lechuri in the Stori river valley. Considering the results of the study, Tebulo and Stori ore fields and Lechuri polymetallic ore occurrence are of particular interest. Unfortunately, because of the limited format of the journal, we could characterize only some ore manifestations.

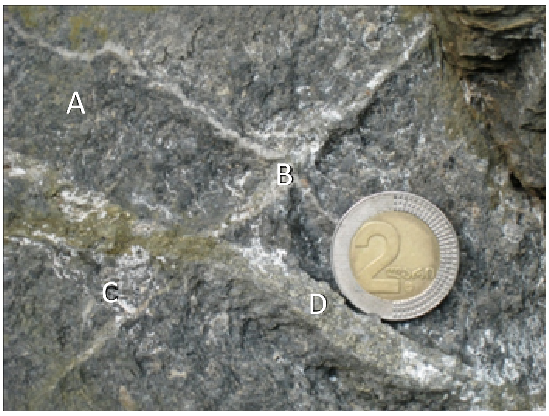

Fig. 2. Silicified and mineralized Lower Jurassic shale, r. Stori canyon. A – silicified and carbonatized shale; B – quartz vein, C – carbonate veins, D – quartz-pyrite-pyrrhotite vein.

Stori Ore Field. Stori ore field presents complex of ore occurrences within the altered zone of the Stori River canyon. The zone is developed on the southern slope of the Great Caucasus. It starts at the beginning of the canyon and traces about 4 km till the Abano bridge over the Stori River. The zone is intersected by Pshaveli-Omalo motorway that made possible its study.

The hydrothermally altered zone of Stori is developed within Sinemurian-Pliensbachian shales and sandstones; only five sections of primary rocks with total length of 1.5 km are preserved along 4 km-long road. Rocks altered at the present erosion level are mainly presented by quartz-sericite-chlorite and quartz-albite-chlorite-epidote associations, which undergo intense pyritization. This fact indicates that hydrotherms were rich in iron and sulfur. These rocks are easily distinguished in the relief because of their distinctive reddish, yellowish and grayish colours. We believe that they are typical hydrothermal phyllitess and prophyllites, which tend to develop around the large porphyry mineralizations [8].

Stori hydrothermal zone was sampled on gold content along the motorway. Over 200 samples were analyzed on ICP-MS device, by 1F15 and 3B methods but without favorable results. However, four zones of general Caucasian trend were allocated in the northern part with a thickness of several tens of meters, in which the gold concentration ranges within 0.01-0.94 g/t. In particular, in the first zone the metal concentration ranges in 0.01 - 0.66 g/t, in the second – 0.01-0.94 g/t, in the third – 0.01-0.68 g/t, and in the fourth – 0.01-0.87 g/t.

Fig. 3. Fragment of massive quartz-pyrrhotite-chalcopyrite ore, Gelia vein.

Three ore occurrences, Gelia, Bendena and Th mineralization were distinguished within the Stori hydrothermal zone in the valleys. Although there might be more ore occurrences it is difficult to trace them because of unaccessibility. A special publication on Stori thorium ore occurrence is already published [9], and some information is given in this paper. The ore occurrence is localized at the north part of the ore field and high concentrations of thorium are associated with carbonate quartz-plagioclase veins, where the content of these elements varies in large range of 40-800 g/t. Such a type of thorium ore occurrences are known in many regions of the world. However, it was first described in the US [10].

Gelia Ore Occurrence is outcropped in the central part of the Stori ore field, on top of the serpentine, in the Gelia ravine, about 200 m hypsometrically above the main road. It represents a coper-pyrrhotitic ore vein formed within a thick tectonic zone and enclosing rocks are quartz-sericite-chloritic metasomatites (Fig. 3). The thickness of the vein ranges within 5-11 m and is continuously traced towards the ravine source on 80-90 m. Further the ravine is continued by impassable rocky cornice, which is intensively oxidized at 250 m length section, which

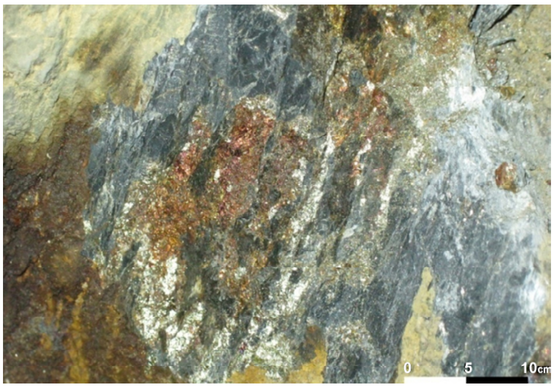

Fig. 4. Orebearing quartz-pyrrhotite-chalcopyrite veinlets in selvage of English vein.

proves existence of a deep mineralized zone.

Gelia vein, which presents a classic example of hydrothermal sulfide mineralization, was studied in detail by the authors. The main mineral of massive ore is pirrhotite, and subordinated ones are chalcopyrite, pyrite and arsenopyrite. Contents of 39 metals were determined in 12 samples of massive quartz-pirrhotite-chalcopyrite ores of the vein. Analyses were made with ICP MS device by 1F15 method. The results obtained are as follows: copper concentration ranges within 350 - 1660 g/t, lead – 11-33 g/t, zinc – 25-35 g/t, arsenic 1500-6400 g/t, cobalt – 100-300 g/t, and iron – 25-35%. As for gold and silver concentrations in massive ores, those elements were not detected. High concentrations of gold, in particular 1.41 and 4.56 g/t, were marked only in two samples from vein selvages. The results of the Gelia vein chemical analysis shows that it presents an iron-rich sulphide mineralization, which is often formed in hydrothermally altered zones existed around the porphyry deposits [8].

Artana Ore Field. In the Aratana ore field ten ore occurences are known. Among them the so called Samchedlo and English ore veins are studied best of all.

Vein Samchedlo is situated in the left rocky cornices of the r. Okhotistskali, 12 km north of the village Artana. The vein is localized in a fault zone of general Caucasian trend (dip 20-30°,< 70-75°), in Plinsbachian shales. The thickness of ore vein amounts 2-2.5 m, and is traced along the strike at about 500-550m. The central part of the vein is built up by massive chalcopyrite-pyrrhotitic brecciated ore. Along with main sulfide minerals chalcopyrite and pyrrhotite, small amount also of galena, sphalerite, ilmenite and cobaltine is represented.

Eighteen samples of Samchedlo vein were analyzed with ICP MS equipment by methods 1F15 and 3B. The following results are obtained: copper concentration in massive ores ranges between 1.40-3.54%, iron – 19.6-61.4%, lead – 17-21 g/t, zinc – 173-610 g/t, cobalt – 118-1040 g/t, Cadmium 8-22 g/t, bismuth – 15-50 g/t, and silver – 2-4 g/t. In massive chalcopyrite-pyrrhotitic ores of the manifestation the elevated content of gold (0.32-1.31 g/t) was detected for the first time. It should be noted that this element was not found by the method 1F15, it was detected only by the method 3B, which was specially designed at AcmeLab for analyzing of gold in sulphide ores.

English Vein is located on the left rocky cornices of the r. Okhotistskali, in 1.5 km to the river head from the outcrop of the Samchedlo vein. It is formed in a tectonic crush zone of general Caucasian trend (dip 50°, < 75°), with the thickness of 4.5-5.0 m. The zone is built up with Pliensbachian brecciated, chloritized and silicified shales, in the middle of which ore body of 1.4-1.8 m thickness is formed. It is represented by pyrrhotite-chalcopyrite lenses, lodes and veinlets (Fig. 4), where small amount of pyrite, galena and sphalerite is detected. A tunnel by length of 38 m and diameter of 2 m is made through the ore body. It should be noted that the cornices undergo intense silicification and malachitization to the south from the vein where some small tunnels were made by English miners in the past.

12 samples of the English vein were analyzed on the same equipment using the methods as for Samchedlo vein. The results of our study are the following: copper concentration in massive ores varies in the range of 1.09-5.14% , iron – 16.4- 61-4%, lead – 6 - 44 g/t, zinc – 140 - 8540 g/t, cobalt - 118 -1040 g/t, cadmium 8-22 g/t, bismuth 19-75 g/t, arsenic 12-28 g/t and silver – 2-4 g/t. In the selvage of the mineralization quartz-pyrite-chalcopyrite veinlets the gold

elevated content was determined for the first time (3.09 g/t). It should be noted that the increased gold content could not be fixed by the method 1F15 and it was still fixed only by the method 3B.

Lechuri Ore Occurence. In the south from the village Lechuri, at about 1.5 km in the valley of the Stori River left tributary, we observed first pyrite-polymetallic ore occurrence, which forms about 2 m high rocky cornices in the riverbed. Ore occurrence is covered by alluvial-delluvial (slide-rocks) deposits that makes impossible its tracing or thickness detection. The left slopes of the valley are represented by cornices constructed by hydrothermally altered quartz-chlorite-sericite shales, crossed by sulfidized quartz veins of different orientation. The zone of 22-25 m thickness is traced for more than 1 km (dip 20-25°, < 40-45°) and is localized within Toarcian shales and sandstones.

Six samples were taken from the massive ores of the above manifestation, and 4 samples – from quartz vein with sulfide mineralization. Metal analyses were made on the ICP-MS equipment by 1F15 and 3B methods. Metal concentration in samples from massive ores varies: Au – 0.02-0.08 g/t, Ag – 5-16 g/t, As – 40-292 g/t, Bi – 7-28 g/t, Cd – 9-26 g/t, Co – 7-21 g/t, Cu – 300-1470 g/t, Pb – 1850-> 10000 g/t, Zn – 3380-> 10000 g/t. Metal concentrations are almost the same in quartz-sulfide veins and amount on average: Au – 0.08 g/t, Ag – 5 g/t, As – 292 g/t, Bi – 9 g/t, Cd – 9 g/t, Co – 7 g/t, Cu – 696 g/t, Pb – 9010 g/t and Zn – > 10000. In accordance with the metal content and distribution type, and also geotectonic position, Lechuri ore occurrence shows great similarities to well-known Philizchay pyrite-pollymetalic deposit, which makes unavoidable its further research.

Tebulo Ore Field outcrops in Tusheti, on the eastern slope of the Tebulo Mountain, at 2700-2900 m altitude and covers about 22 km^2 area. The territory is reffered to as "madniani khorkhi" in Tush toponym that means "ore place". The ore-bearing rocks are mainly represented by Pliensbachian terrigenous sediments, which are intersected by gabbro-diabase and diorite bodies. The research area is situated within the node of the Caucasian and Transcaucasian deep faults, which makes the ore-field more interesting. Sedimentary rocks form overturned to south anticline structure (dip 40-50°, <65-75°), within which brecciated zone of 220 m thickness with submeridional strike (dip 80-90°, <70-75°) is developed crossing the anticline.

Fig. 5. Massive pyrite-polymetallic mineralization, Tebulo ore field.

The small ridge situated in the central part of the ore-field divides the area into two parts - the West - and the East parts. In the western part, on the right slope of the r. Dakvekhis-Khevi *mutually parallelly oriented* 8 mineralized ore bodies are outcropped, which represent massive quartzites formed in crushed shales, and are cut up by quartz, pyrite, chalcopyrite and galena veinlets. The thicknesses of these bodies vary in the range of 1.5-6 m, and are separated by packages of brecciated shales and form ore zone with 35 m thickness. 48 samples from the ore zone were analysed on five metals (Au, Ag, Cu, Pb, Zn) at the laboratory of "RMG Gold" Ltd. According to this analysis, copper concentration in ores ranges 0.1-2.10%, lead – 0.01 - 0.92%, and zinc – 0.01- 0.98%, silver – 4.0-21.1 g/t, and concentrations of other metals are marked within the Clark limits. It should be noted that gold content was detected almost in all samples and its concentration varied in the range of 0.03-0.64 g/t, which is a good result for the complex deposit of such scale. In addition, it should be noted that an approximate concentration of Au at world-class deposit "Olympic Dam" amounts 0.5 g /t [10].

In the eastern part of the ore-field, the shales undergo intense crush, breciation and silicification, while rocky cornices in the south-east of the Tebulo Mountain are entirely build up by hydrothermally altered quartz-sericite-chlorite formations (Fig. 5), which are similar to alterations formed on the top of porphyry deposits. On the right slope of the r. Tebulo, copper-polymetallic mineralization massive veins of 1.3-1.7 m thickness outcrop hypsometrically 250-300 m down the basis of the cornices. To define the exact number of the veins is impossible due to slide rocks cover. Large ore boulders (1.-1.5 m^3) torn from these veins are met in several places in the valley (possibly Shamil carried ore to Dagestan in such blocks).

Fourteen samples of massive pyrite-polymetallic ores from Tebulo ore field were analysed on content of 39 metals (tests were conducted at AcmeLab, on ICP-MS by method 1F15). The results obtained are as follows: copper concentration in the range of 500-725 g/t, lead – 1300-1430 g/t, and zinc is more than 10.000 g/t in all samples. Average concentrations of other elements are as follows: Fe – 25.3-30.9%, Cd – 452.3-745.4 g /t, Co – 82.8-146.7g /t, Bi – 72.3 -81.9 g/t, Mn – 56.-721 g/t, Ni – 21.7-18.4 g/t, and As – 178.8-219.0 g/t, and concentration of other elements are within the Clark limits. As for the silver and gold, their encreased concentrations were detected in all samples and ranged within 8.19-10.57 g/t (Ag) and 0.029-0.141 g/t (Au).

Thus, the entire spectrum of useful components with significant concentrations (Ag, Au, Cu, Pb, Zn, Co, Cd, Bi, Mn, Fe) is presented at Tebulo ore field. As for the ore mineralization scales, it is really impressionable and there is no doubt that it requires further detailed study.

Discussion

Metallogenic research carried out in the segment showed that from the point of view of genesis, quantity and composition there is a large spectrum of ore occurences in the Georgian segment of the Eastern Caucasus. Most of them does not outcrop at the present erosion level and is covered by sedimentary cover or is located under the altered zones. Taking into account a number of parameters, these ore manifestations generally belong to a hydrothermal type genetically related to magmatic pockets [8].

Traditionally in the eastern Greater Caucasus two zones of nonferrous metal ore occurrences are marked out – the south- and the north zones [11]. In the south zone copper-pyrrhotitic manifestations (Samchedlo, English, Katsdag) are localized and in the north zone - pyrite-polymetallic ones (Abano, Ilurta, Tebulo). But this zoning is broken by Lechuri, Loduani, Kizil-Dere and other ore manifestations. It is believed that formation of copper-pyrrhotitic ores to be genetically related to base- and intermediate magmatizm, and that of pyrite-polymetallic ones are associated with acid magmatic activity [12]. The conducted works have shown that, in case of one ore-forming centre, composition of hydrothermal ore mineralization is partly determined by spatial connection between magmatic centre and ore formation area. Preferentially, copper-pyrrhotitic ores are formed near ore-forming centres and pyrite-polymetallic ores – apart from it. This circumstance, in our opinion, is conditioned by the temperature characteristic of nonferrous metal solidus. In particular, copper starts solidification below 1085°C, zinc – at 419.5°C, and lead – at 327°C, which causes precipitation of these metals at different distances from the ore-giving centres.

Conclusion

Thus, based on the analysis of the conducted metallogenic research one can conclude that numerous hydrothermal ore occurrences localized in the Georgian segment of Eastern Greater Caucasus represent magmatic-hydrothermal genetic formations, which were formed in different thermodynamic conditions. There is no doubt that Artana, Loduani, Chelti and other similar ore occurrences are small-scaled manifestations for present industrial demands. Unlike them, Stori and Tebulo ore fields are large-scaled, around which the thick quartz-sericite-chlorite-pyritic and albite-epidote-chlorite-pyritic zones are developed, which is characteristic of porphyry deposits. The both orefields, besides traditional division (copper-pyrrhotite and pyrite-polymetallic), could be ascribed to iron oxide-gold-nonferrous metal hydrothermal genetic type because of high concentartion of iron oxide (> 10%) in both mineralized areas [8]. It should be noted that iron content in mineralized zones of the region was first determined by the authors. Here, iron is mostly represented by oxides, which is very important from a practical point of view and should be studied.

Lechuri ore occurrence, which was found by us, is of great interest. Such mineralization shows significant similarity to Filizchay pyrite-polymetallic deposit by its geological position and mineralogical-geochemical parameters. Taking into account this fact, it is necessary to study the ore manifestation in detail. It should be noted that elevated concentrations of gold in the region were defined for the first time. From this point of view Tebulo ore field should be highlighted, where gold content was detected in both massive polymetallic ores and silicified zones that should be considered as one of the most important results of our study.

Finally, we note that it is necessary to undertake a more detailed metallogenic research in the Georgian segment of the eastern Greater Caucasus in future, because there are many arguments that there, can also be detected important ore fields, such as in neighboring Azerbaijan and Dagestan.

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გეოლოგია

აღმოსავლეთ კავკასიონის საქართველოს სეგმენტის მადანგამოვლინებები: ახალი კვლევის შედეგები

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** ილიას სახელმწიფო უნივერსიტეტის საბუნებისმეტყველო მეცნიერებათა და საინჟინრო ფაკულტეტი, თბილისი*
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(წარმოდგენილია აკადემიის წევრის დ. შენგელიას მიერ)

აღმოსავლეთ კავკასიონის საქართველოს სეგმენტში (თუშეთის და კახეთის რეგიონების ფარგლები) მეტალოგენური კვლევის თითქმის 30-წლიანი პაუზის შემდეგ ავტორებს საშუალება მიეცათ, რეგიონში ჩაეტარებინათ ახალი გეოლოგიური ძებნითი სამუშაოები. შესწავლილ იქნა უკვე ცნობილი თებულოს, ილურთას, საცხვრე ხორხის, აბანოს, ქვაჩადალას, ართანას, ლოდუანის, ჩელთის, შაროხევის და არეშის მადანგამოვლინებები. ამასთან ერთად, მიკვლეულ იქნა ახალი საინტერესო

მადანგამოვლინებები მდ. სტორის ჰიდროთერმულად შეცვლილ მძლავრ ზონაში (გელია, ბენდენა და თორიუმიანი) და სოფელ ლეჩურთან – კოლჩედანურ-პოლიმეტალური. ეს უკანასკნელი იმსახურებს დიდ ინტერესს, რადგანაც იგი ლოკალიზაციის გეოლოგიური პოზიციით და მინერალოგიურ-გეოქიმიური პარამეტრებით მნიშვნელოვან მსგავსებას ავლენს ფილისჩაის კოლჩედანურ-პოლიმეტალურ საბადოსთან, რის გამოც აუცილებელია ამ მადანგამოვლინების შემდგომი დეტალური შესწავლა. ჩვენ მიერ ჩატარებული კვლევის შედეგად რეგიონში პირველად დაფიქსირდა ოქროს ამაღლებული კონცენტრაციები, მათ შორის, აღსანიშნავია თებულოს მადნიანი ველი, სადაც ოქროს ანომალური შემცველობები განისაზღვრა როგორც მასიურ პოლიმეტალურ მადნებში, ასევე მეორად კვარციტებშიც, რაც ჩვენი კვლევის ერთ-ერთ მნიშვნელოვან შედეგად უნდა მივიჩნიოთ. გარდა ამისა, შესწავლილი მადანგამოვლინებები ხასიათდებიან აგრეთვე თანამედროვე მაღალტექნოლოგიური მრეწველობისთვის ისეთი მნიშვნელოვანი ელემენტების სამრეწველო კონცენტრაციებით როგორიცაა თორიუმი, ბისმუთი, კობალტი და კადმიუმი. სინჯების ანალიზი ჩატარდა ვანკუვერის (კანადა) AlxChemex ლაბორატორიაში ICP-MS დანადგარზე სხვადასხვა მეთოდებით, ტაივანის ნაციონალური უნივერსიტეტის და შპს "CMG"–ის (საქართველო) ქიმიურ ლაბორატორიებში.

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