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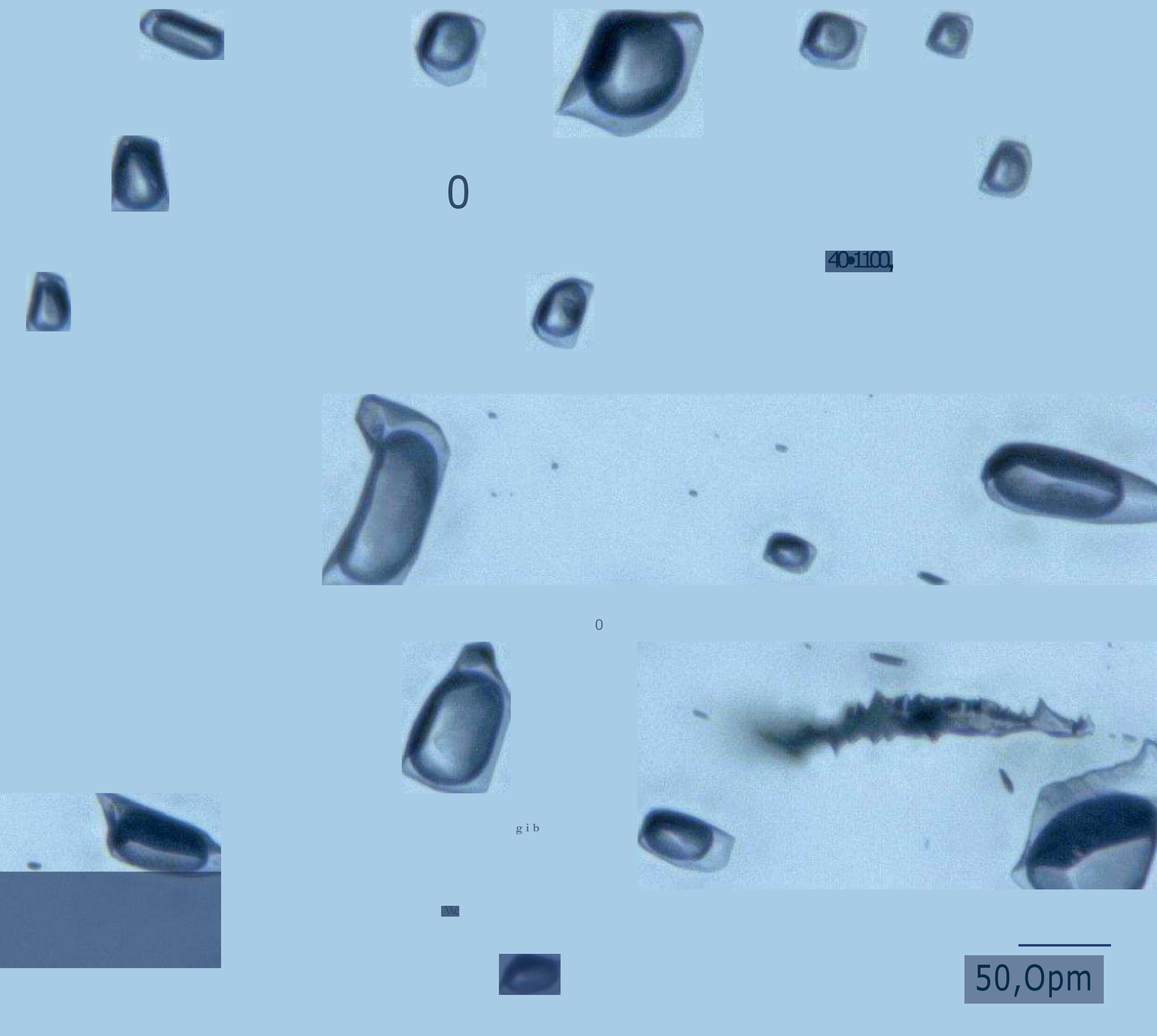

Mineral Resources in a Sustainable World

13th Biennial SGA Meeting
24-27 August 2015, NANCY, FRANCE

Proceedings

Volume 2

Edited by
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Strategic metals: sources and ore-forming processes

Ore-Forming Processes and Ore Occurrences of the Eastern Greater Caucasus Georgian Segment

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Abstract. In the Eastern Greater Caucasus Georgian segment Lower-Middle Jurassic shales and sandstones experienced crush, hydrothermal alteration and ore mineralization processes. At some hydrothermally altered areas mainly copper-pyrrhotitic and pyrite-polymetallic ores were formed. Already known ore occurrences were studied and, at the same time, new and interesting ore occurences were discovered in the hydrothermally altered zone in the r. Stori canyon (Bendena, Gelia, and enriched with Th zone) and pyrite-polymetallic ore mineralization at the village Lechuri. The latter should be of great interest, since it shows lots of similarities to Filizchay pyrite-polymetallic deposit by its geologic position and mineralogical-geological parameters, which makes necessary further detailed study of the area. It should be noted that at some areas, on the result of conducted research, for the first time the increased concentrations of Au (at Artana and Tebulo ore fields) were reported. At Tebulo ore field gold increased concentrations were defined as in massive polymetallic ores, so - in hydrothermally altered zones, which should be considered as one of the most important results of the research study. These ore occurrences are also characterized with the significant concentrations of Th, Bi, Co and Cd.

Keywords. Eastern Caucasus, Georgia, ore-forming, ore occurences.

1 Introduction

More than 100 quartz-pyrite-pyrrhotite and copper-polymetallic ore manifestations of different scale are detected in the eastern Greater Caucasus Georgian segment, which are represented by impregnations, lodes, veins and massive sulphide bodies. Our research interest to the above area is mainly caused by the fact that, in the 60-ies of the last century in the neighboring Azerbaijan (southern slope of the Greater Caucasus) within the same geological structure and sediments, were discovered important stratiform pyrite-copper-polymetallic deposits: Katsdag, Filizchay and Katekh (Novruzov and Agaev 2010). In addition, almost in the same years, on the northern slope of the Greater Caucasus was opened copper-polymetallic deposit Kizil-Dere in Dagestan, Russian Federation (Bogush and Kurbanov 1999). After almost thirty years gap in research of the above segment, the authors conducted new geological prospecting works, within the region. In particular, it was carried out more detailed study of geological construction, magmatic and post-magmatic hydrothermal processes and ore occurrences. The results allowed the researchers to make essential corrections in geological structure of the region, and in metallogenic point of view, significant news were uncovered.

2 Material and methods

During the geological field works over 200 petrographic samples, and about 700 geochemical samples were taken. Geochemical analysis on metal content in samples were conducted at AcmeLab Vancouver laboratory at the ICP-MS facility, by different methods, and also at the laboratory of "CMG" Ltd (Georgia) by the atomic absorption spectrometry method.

3 Geological settings

The Greater Caucasus represents a Phanerozoic orogenic unit formed between the Euro-Asian south continental margin and Arabian plate, and is stretched on 1200 km among the Black and Caspian seas (fig.1). The Greater Caucasus is the northernmost terrane of the Caucasus orogen, which is accreted on the southern margin of the Euro-Asian continent. It is currently a folded-nappe formation, in which two major structural stages are distinguished: a Pre-Mesosoic crystalline basement and Meso-Cenozoic sedimentary and volcanic-sedimentary cover (Gamkrelidze and Shengelia 2005).

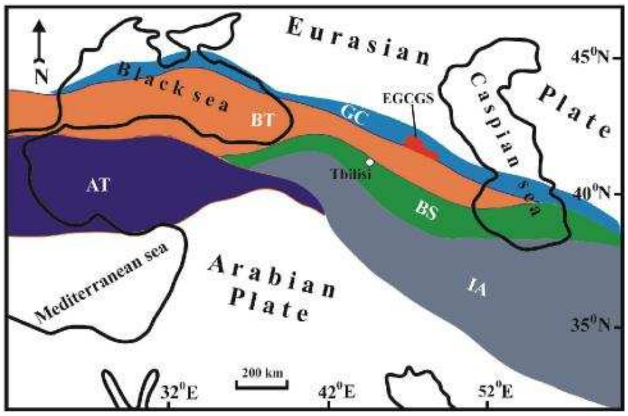

Figure 1. Tectonic zoning of the Caucasus and adjacent area on the basis of the terrane analysis Adapted after I. Gamkrelidze (1997). Terranes: GC- Greater Caucasian, BT-Black Sea-Central Transcaucasian, BS-Beiburt-Sevanian, IA-Iran-Afganian, AT –Anatolian. EGCGS- Eastern Greater Caucasus Georgian Segment.

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

On the southern slope of the Greater Caucasus the research area 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 - the River Alazani of Tusheti and its tributaries (Tusheti region) (fig.2).

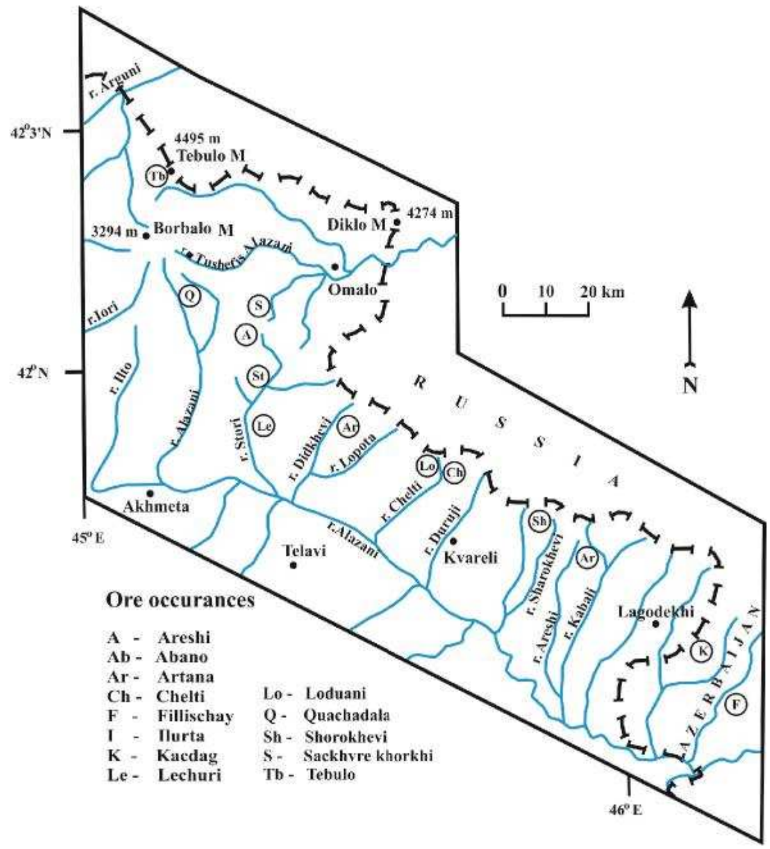

Figure 2. Schematic map of main ore occurences in the Georgian Segment of the Eastern Greater Caucasus and neighbouring Azerbaijan

The sedimentary cover of both segments is approximately the same and is mainly represented by intensively folded Lower-Middle Jurassic schists, shales and sandstones (Topchishvili 1996), and subordinated dacite-andesite-basaltic layers and tuffs (Akimidze 2010). In the Middle Jurassic this sedimentary cover was intersected by numerous magmatic bodies of different composition and thickness. The whole complex of rocks has experienced intensive crush, brecciation, hydrothermal alteration and ore mineralization (Okrostsvaridze et al. 2011).

4 Ore-forming processes

The research conducted in the eastern Greater Caucasus Georgian segment showed that ore mineralization processes are related to activities of hydrotherms formed in magmatic centers. As it is known hydrothermal mineralizations represent a big class, which includes economically so important deposits as porphyry, epithermal, orogenic Au and others (Goldfarb et al. 2005; Ridley 2013).

Field observations showed that hydrothermal alterations and ore mineralization processes occur only in Lower- Middle Jurassic formations, and these processes don't take place within the younger formations. This fact is one of the important arguments indicating that ore mineralization processes of the Greater Caucasus Kakheti segment genetically are linked to Bathonian granodioritic magmatic activity. Ore mineralization is preceded by hydrothermal alteration of rocks, during which chlorite+sericte, quartz+sericite +pyrite (phyllic), quartz+sericite+chlorite+pyrite (propylitic), epidote+ chlorite+calcite+pyritic associations were formed. Within the later crack systems of these rocks quartz-pyrite-pyrrhotitic, quartz-chalcopyritic – and, at the end, quartz-calcite-polymetallic associations have been crystallized from hydrotherms (fig.3).

5 Ore Occurrences

The research of ore occurrences in the eastern Greater Caucasus Georgian segment has a long history. 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 at the present erosion level form impregnations, lodes, veinlets or massive ore bodies. We have 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 the 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 orefields and Lechuri polymetallic ore occurrence are of particular interest. Below is given brief characterization of some ore manifestations.

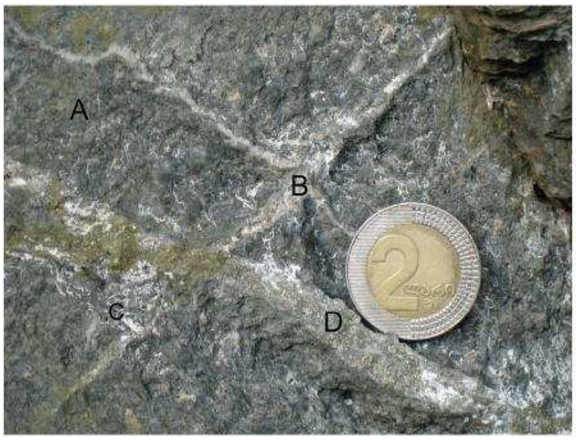

Figure 3. Silicified and ore mineralized Lower Jurassic shale, r.Stori canyon. **A.** silicified, sericitized and carbonatized shale; **B.** quartz vein, **C.** carbonate veins, **D.** quartz-pyritepyrrhotite vein.

5.1 Stori orefield

It represents complex of ore occurrences within the altered zone of the Stori River canyon on the southern slope of the Great Caucasus and is traced about 3.7 km.

Rocks, altered at the present erosion levels, are mainly presented by quartz-sericite-pyrite and quartz-sericite-chlorite-pyrite mineralizations, 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 phyllitic and prophyllitic, which tend to develop around the large porphyry deposits (Ridley 2013).

The Stori hydrothermal zone was sampled on gold content along the motorway Phshaveli-Omalo. Over 200 samples were analyzed on ICP-MS device, by 1F15 and 3B methods but we have not got favorable results. However, four zones of general Caucasian trend have been allocated in the northern part with a thickness of several of hundred 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.

Three ore occurrences – Gelia, Bendena and zone with Th mineralization, were distinguished within the Stori hydrothermal zone in the valleys. The thorium occurrence is localized at the north part of the ore field and high concentrations of thorium are associated with quartz-plagioclase veins, where the content of this element varies in the large range from 50 g/t to 3880 g/t. It should be noted that in addition to thorium high concentrations of bismuth are also marked in this occurrences (55 g/t – 4800 g/t).

5.2 Artana orefield

In the Aratana ore field ten ore occurrences are known. Among them the ore veins Samchedlo and Inglisuri 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 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. 18 samples of vein Samchedlo were analyzed and the following results were obtained: copper concentration in massive ores ranges between1.40-3.54%, 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 increased content of gold was detected for the first time (0.32-1.31 g/t).

Vein Inglisuri is located on the left rocky cornices of the r. Okhotistskali, in 1.5 km distance from the outcrop of the vein Samchedlo. It is situated in a tectonic crush zone with general Caucasian strike (dip 50°, < 75°), with capacity 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 thick is formed. It is represented by pyrrhotitechalcopyrite lences, lodes and veinlets (fig. 4), where small amount of pyrite, galena and sphalerite is detected. A tunnel by length of 38 m and 2 m diameter is made through the ore body. It should be noted that the cornices, in the south from the vein, experience intense silicification and malachitization, where some small tunnels were made by English miners in the past.

Our research data for the vein Inglisuri are as follows (12 samples were analyzed on the same equipment and by using the methods as for vein Samchedlo): copper concentration in massive ores varies in the range 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, f arsenic 12 - 28 g/t, and silver - 2 - 4 g/t. In the selvage of the mineralization quartz-pyritechalcopyrite veinlets gold increased content was determined for the first time (3.09 g/t). It should be noted that the increased gold content couldn’t be fixed again by the method 1F15 and it was still fixed only by method 3B.

5.3 Lechuri ore occurrence

South from the village Lechuri, approximately 1.5 km in the valley of the Stori River left tributary, for the first time was observed pyrite-polymetallic ore occurrence, which forms about 2 m height rocky cornices in the riverbed. Ore occurrence is covered by alluvial-delluvial deposits that make impossible its tracing or thickness detection. Metal concentration of Lechuri ore (16 samples) 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 > 10000 g/t, Zn > 10000 g/t.

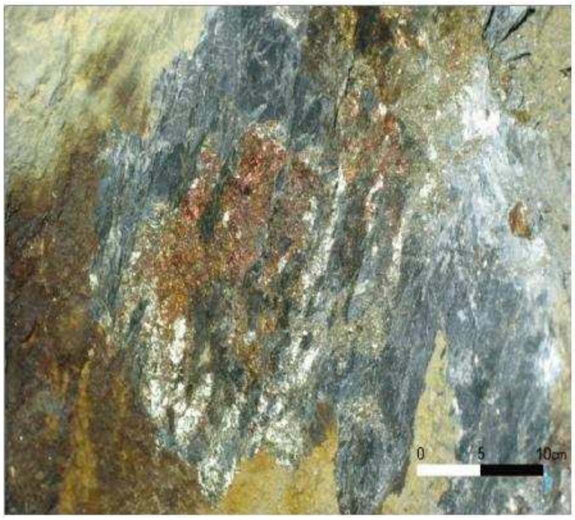

Figure 4. Ore-bearing quartz-pyrrhotite-chalcopyrite veinlets in selvage of vein " Inglisuri ".

5.4 Tebulo orefield

Tebulo orefield outcrops in Tusheti, on the eastern slope of the Tebulo Mountain, at 2700-2900 m.a.s.l. and covers about 22 km^2 area. In the western part of the ore field oriented parallel to each other 8 mineralized ore bodies are outcropped, which represent massive quartzites. 48 samples from this zone were analyzed and Au contents were detected almost in all samples and the concentrations vary in the range of 0.03 - 0.64 g/t. In the eastern part of the ore-field, the shales undergo intense hydrothermal alteration and is represented by quartz-sericite-chlorite formations. 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. Defining 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. Metal concentration in this ore (14 samples) varies: Cu - 500-725 g/t, Pb -1300-1430 g/t, Zn >10.000 g/t, 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. As for the silver and gold, their increased concentrations were detected in all samples and range within 8.19-10.57 g/t (Ag) and 0.029-0.141 g/t (Au).

6 Conclusion

Thus, from the analysis of the conducted metallogenic research could be concluded that numerous hydrothermal ore occurrences localized in the Eastern Greater Caucasus Georgian segment represent magmatichydrothermal genetic formations, which were formed in different thermodynamic conditions. There is no doubt that Artana and other similar ore occurrences are small-scaled manifestations for modern industrial demands. In contrast, Stori and Tebulo orefields are large-scaled, around which thick quartz-sericite-chlorite-pyritic and albite-epidote-chlorite-pyritic zones characteristic for porphyry deposits are developed. The both orefields, besides traditional division (copper-pyrrhotite and pyrite-polymetallic), could be belonged to iron oxide-gold-nonferrous metal hydrothermal genetic type, because of high concentration of iron oxide (> 10%) in both mineralized areas (Ridley 2013). It should be noted that iron content in mineralized zones of the region was firstly determined by the authors. Iron mostly is represented by oxides, which is very important in practical point of view.

Lechuri ore occurrence, which was found by the authors, is of great interest. The mineralization shows similarity to Filizchay pyrite-polymetallic deposit by its geological position and mineralogical-geochemical parameters. It is necessary further detailed study of the ore manifestation. Also it should be highlighted Tebulo ore field, where gold content was determined as in massive polymetallic ores, so in silicified zones.

In conclusion we note that it is necessary to undertake more detailed metallogenic research in the eastern Greater Caucasus Georgian segment in future, as there are a lot of arguments that here too can be detected as important fields as in neighbouring Azerbaijan and Dagestan.

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References

Akimidze (2010) Late Pliensbachian-Early Toarsian Volcanizm of the Trans-Alazani Kakheti. Proceedings of the Alexandre Janelidze Institute of Geology, New series 125:164-172

Bogush and Kurbanov (1999) Genetic model of the Kizil-Dere copper-pyrite deposit. Proceedings of High Schools, North Caucasus reg, 4, pp 94-100 (in Russian)

Gamkrelidze I (1997) Tettanes of the Caucasus and Adjacent Areas. Bull. Georg. Acad. Sci 155:75-81

Gamkrelidze I, Shengelia D (2005) Precambrian-Paleozoic Regional Metamorphism, Granitoid Magmatism and Geodynamics of the Caucasus. Scientific World, Moscow, 458 p (In Russian)

Goldfarb R, Baker T, Dube B, Groves D, Hart C, Gosselin P (2005) Distribution Character and Genesis of Gold Deposits in Metamorphic Terranes. Econ Geol 100th Anniversary:407-450

Novruzov, Agaev (2010) Mineralogical-geochemical zonality of the Phylizchay pyrite-polymetallic deposit (Greater Caucasus). In: "Geological Sciences and Industrial Development of Kazakhstan" Alma-Ata. pp 211-215 (in Russian)

Okrostsvaridze A, Tormay D (2013) Phanerozoic Continental Crust Evolution of the Inner Caucasian Microplate: The Dzirula Massif. Episodes 36(1)31-39

Okrostsvaridze A, Akimidze K, Akimidze A, Bluashvili D (2011) The First Data on Industrial Concentration of Thorium and Bismuth in Hydrothermally Altered Lower-Jurassic Clay Shales of the Stori Canyon (Southern Slope of the Greater Caucasus, Kakheti). Bull Georg Acad Sci 5:76-82

Ridley J (2013) Ore deposit geology. Cambridge University Press, 398 p

Topchishvili M (1996) Stratigraphy of the Lower Jurassic formations of Georgia. Proceedings of the Geological Institute of Academy of Sciences of Georgia. New Series 108:216