Felsitic Magmatism and Thorium - Bismuth Ore Mineralization in the Greater Caucasus Kakheti Segment, Georgia

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Abstract. The Greater Caucasus represents a Phanerozoic collisional orogen which is formed along the Euro-Asian North continental margin between the Black and Caspian Seas and is extended over 1200 km distance between the Black and Caspian seas, and considered as a terrane of the first order, which is accreted to the south margin of the Euroasian continent. The Kakheti segment is located on the eastern part of the southern slope of the Greater Caucasus and is mainly formed of strongly folded Lower Jurassic clay-shales and mafic volcanic-sedimentary formations. According to geophysical data these sediments are located on oceanic - or transitional crust. Ore mineralization is related to hydrothermally altered zones, which are significantly enriched by rare metals – thorium and bismuth, and also by gold, copper, zinc, lead and cobalt.

Keywords. Greater Caucasus, thorium, bismuth, mineralization.

1 Introduction

The studied area is located on the southern slope of the Greater Caucasus, in the central part of Kazbeg-Lagodekhi tectonic zone (Gamkrelidze, 1997). It is mainly composed of thick series of Lower Jurassic shales and sandstones (Topchishvili, 1996). Prior to our study, it was considered that in the Kakheti segment of the Greater Caucasus Lower Jurassic shales underlie the so-called coarse-grained "arkose sandstones" of Sinemurian age (Adamia, 1968), or - Upper Paleozoic (Krestnikov, Robinson, 1947; Giorgobiani, 2003). Works carried out by us have shown that these rocks actually represent hypabissal dykes of felsic composition that caused intense hydrothermal silicification and sulphide mineralization of cataclasic host rocks.

There are four relatively large isolated outcrops of these felsic hypabissal dykes: Speroza, Stori, Siptiskhevi and Lopota (fig.1). The thickest outcrop of this complex is Speroza massif, which, in the present relief, has a lenticular shape of general Caucasian strike with length of 14 km and a maximum thickness of 4.7 km. In the Makhvali River canyon is clearly seen that the Speroza

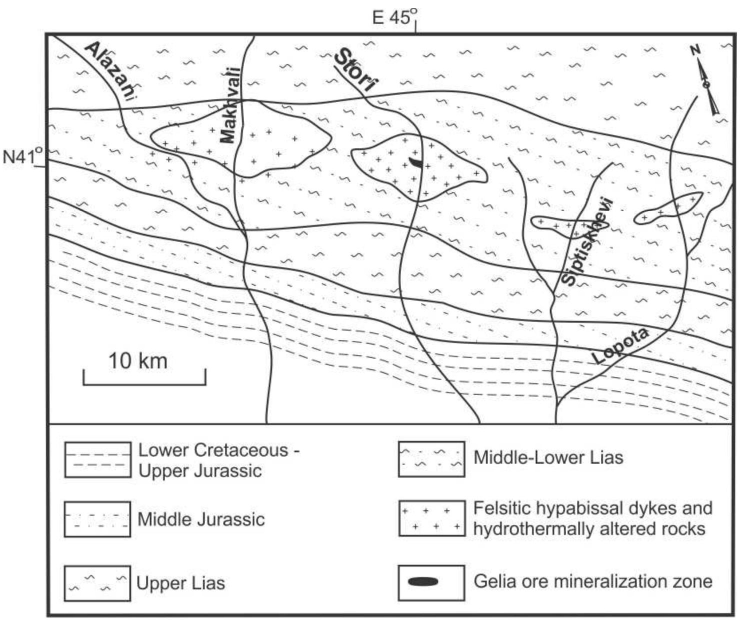

Figure 1. Schematic Geologic Map of the Greater Caucaus Southern Slope Kakheti segment

massif represents the area of mesothermal hypabissal magma intrusion.

In the central part of the massif quartz-feldspar melts and fluids entirely impregnated hosting Lower Jurassic clay-shales, which are preserved only as fragments. At the periphery of the massif intensity of magmatic injections decreases and are represented in isolated dykes and hydrothermally altered zones with a thickness up to several meters. It should be noted that the post-magmatic intense tectonic movements complicated the intrusion contacts, although detailed field observations indicate that the initial contacts were clearly magmatic, as evidenced by the different size xenoliths of Lower Jurassic clay-shales in hornfels in the contact zones, as well as other numerous geological factors.

2 Description of ore mineralization

In the section of the Stori River, which can be traced at 4 km, recent erosion exposes upper parts of the zone of hypabissal quartz-feldspar felsic magma interaction; in the result hydrothermally altered rocks dominate in the outcrop. Although there had been numerous quartz-feldspar dikes that transect Lower Jurassic shales, ranging in thickness from single to tens of meters. In this section magmatic activity is ended with hydrothermal carbonate veins that fill the newly formed cracks. It should be noted that the Stori cross-section as from the north, so from the south, is limited by thick gabbroic intrusions, although small bodies of similar generation are marked within the above cross-section, intrusion of which anticipated felsitic magmatism. Unlike from other outcrops this section differs by its intense sulfide mineralization, which in shearing zones often forms quartz-pyrite-pyrrhottitic veins.

Quartz-feldspar felsites are light grey, often porphyritic, massive, dense formations, with porphyry isolations of quartz, acid plagioclase and microcline. The bulk is characterized by microcrystalline felzitic structure and consists of the same minerals, although there are observed the flakes of muscovite and sericite, and accumulations of ore minerals of irregular shape, which are confined to fragmented grains of quartz. Based on chemical composition these rocks represent granodiorite-dacites and granite-rhyolites (Table 1). They are characterized by high grade of SiO_2 (73-78%) and low grade of Al_2O_3 (10-11%) and CaO (1-2%), which is typical for intensively fractioned

Table 1. Chemical analyses of some hypabissal felsic rocks and their A/CNK parameters

№	1/09	16/09	30/09	39/09	60/09	84/09
SiO_2	76.5	72.5	74.3	76.2	75.0	76.8
TiO_2	0.25	0.28	0.27	0.18	0.25	0.22
Al_2O_3	10.1	11.24	10.5	10.54	11.13	9.20
Fe_2O_3	2.20	0.60	-	0.76	0.40	-
FeO	0.80	1.85	3.21	1.75	2.18	3.37
MgO	1.24	1.68	1.50	1.56	1.72	1.52
MnO	0.10	1.19	0.11	0.12	0.10	0.08
CaO	1.80	2.17	1.10	1.08	1.79	2.00
Na_2O	5.47	4.78	3.38	3.80	5.35	1. 12
K_2O	1.28	1.25	2.19	3.15	1.30	2.64
P_2O_5	0.12	0.15	0.08	0.13	0.12	0.08
H_2O	0.04	0.06	0.28	0.22	0.04	0.20
A/CNK	0.80	0.86	0.92	0.84	0.89	0.93

Samples № 1-09, 16-09, 39-09– from r. Makhvali section; samples: № 60-09, 84-09, 86-09 - from Stori canyon.

magmatic formations.

Petrochemical studying of the rocks corresponds to depleted in alumina, acid igneous rocks in which CNK>A>NK and are genetically related to subduction zones and localized in islandarc complexes. Parameter A/CNK in all formations is less than one, which may indicate their mantle origin and formation in the result of fractional crystallization of mafic magma (Clarke, 1992). As for the magmatism age, we still have no isotopic dating, but judging from geological data, and then it must match the early Cenozoic, as the exhumation of these deposits on the hypabissal level must have occurred at about the same time interval. If the young age of these rocks is confirmed, then their genesis may relate to mantle plumes (Okrostsvaridze, 2011), since subduction processes in this period along the southern margin of the Greater Caucasus were ceased.

25 Samples of quartz-pyrite-pirrhottitic zones and hydrothermally altered rocks from around Stori canyon section were transferred to the laboratory of ACMELABS (Canada, Vancouver), analyses were conducted at the facility ICP-MS. The results showed abnormally high concentrations of Th and Bi in the hydrothermally altered rocks (Table 2). And quartz-

Table 2. Chemical analyses of ore elements of some hydrothermaly altered rocks from Stori canyon
(Au, Ag, Hg data given in ppb, other elements – in ppm)

№	8-09W	8-09B	10-09	11-09	12-09
Mo	0.67	0.13	0.94	0.70	0.39
Cu	26.14	1414	191.3	103.06	64.91
Pb	5.81	33.32	18.42	12.68	22.16
Zn	6.0	0.5	6.8	7.8	5.9
Ag	6.1	275.5	7.2	13.6	12.4
Ni	0.19	13.95	0.11	0.56	0.22
Co	0.40	1.41	2.11	2.02	6.65
Mn	0.13	16.48	0.09	1.03	0.15
As	0.28	20.16	0.32	0.84	1.09
U	0.017	0.003	0.044	0.034	0.055
Au	4.3	2.1	5.5	6.3	2.4
Th	50.9	3842	41.4	203.8	99.0
Sr	13	483	179	108	84
Cd	4.2	64.0	30.7	8.2	37.7
Sb	3.2	118.3	13.5	7.9	20.6
Bi	197	4806	234	319	396
V	1.39	18.90	2.68	3.00	3.91
La	5.9	8.8	20.9	12.5	8.1
Sc	0.4	1.4	0.6	0.6	1.2
Tl	0.04	0.04	0.11	0.06	0.16
Hg	5	119	32	22	8
Te	-	1.20	0.08	0.53	0.03
Ga	1.4	1.3	1.0	1.2	1.3
Cr	1.8	2.6	12.8	1.5	9.2
Ba	15.9	9.0	24.3	31.9	29.6
W	0.1	-	0.2	6.3	0.2

pyrite-pirrhoititic zone is enriched with gold, copper, zinc and lead. Gold average concentration amounts 1 g/t, but in some samples from Gelia ore lode zone (apparent thickness - 2-7 m, can be traced on 300 meters) it reaches 6 g/t; in the same zone copper grade reaches 4000g/t, zinc – 2000 g/t, lead – 1500 g/t, and cobalt – 273 g/t (fig. 2).

Figure 2. Gelia Quartz-pyrite-pyrrhhotitic vein from Story Canyon

In hydrothermally altered rocks of the studied section Th content varies 40 g/t-120 g/t, and Bi - 200 g/t-800 g/t, but the grades are even higher in the quartz-pyrite-pirrhottite areas. The highest content of these elements is fixed in the host rocks near Gelia, where the maximum grade of thorium reaches 3842 g/t, and bismuth - 4806 g/t (fig. 3). As microscopic studies showed, thorium is mainly represented by mineral thorite (ThSiO4), which fills the voids of crushed quartz, and bismuth – by bismuthinite (Bi_2S_3).

Figure 3. Zone with high concentration of thorium and bismuth

Thus, in the studied rocks contents of Th and Bi are abnormally high. If we take into account that thorium is considered as the main energy source of the third millennium of our civilization (Windham, 2007; Gosen et al., 2009; Martin, 2009) we assume that it is necessary to carry out comprehensive exploration works in the region. It should be noted, that this anomaly of ore and rare elements further strengthens our assumption on the magmatic formation of felsitic quartz-potash feldspar rocks, and it is possible that they are genetically related to the activity of mantle plumes, as it is mantle-plume flows and fluids form clusters of ore and rare elements like examined by us above.

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References

Adamia Sh (1968) Pre-Jurassic Formations of the Caucasus. Proceedings of Inst. Geology Georg., New Series, v. 16, 294

Gamkrelidze I (1997) Terranes of the Caucasus and Adjacent Areas. Bull. Georg. Acad. Sci, v.1955, 3, 90-93

Giorgobiani T (2003) On the origin of horst-anticlinorium of the main ridge of the Eastern Caucasus. Reports of Acad. Sci, v. 388,3 363-368

Clarke D (1992) Granitoid rocks. Chapmpen and hall, London

Gosen B, Gillerman V, Armbrustmacher T (2009) Thorium Deposite of the United States – Energy Resources for the Future? US Geol. Surv. Circular 1336, 21

Krestnikov V, Robinson V (1955) On the North Kakhetian Paleozoic Formations. Reports of the USSR Acad. Sci, v.105, 5, 45-51

Martin R (2009) Uranium is So Last Centory – Enter Thorium, the New Green Nuke. Wired magazine http://www.wired.com/magazine/2009/12/ff_new_nukes/Wired magaz., Accessed 20 January 2010

Morariu D, Nouval V (2009) Cretaceous Play – New Exploration Potential in the Eastern Georgia. Neftegasovaya Geologia, 4 2-14

Okrostsvaridze A (2011) Mantle Plume Conception: A New Geological Paradigm? Intellect, Tbilisi

Topchishvili M (1996) Stratigraphy of Lower and Middle Jurassic Formations of Georgia. Proceedings of Inst. Geology Georg., New Series, v. 108, 314

Windham C (2007) An Insight into the Geology, Exploration and Devcelopment of Thorium. Nuclear Energy Review, II, 103-110