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Geology

Thorium - Future Energy of Modern Civilization and its Ore Occurrences in Georgia

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ABSTRACT. In light of exhaustion of hydrocarbons reserves a new energy resource search is of vital importance for modern civilization. At time of energy resources crisis, the radioactive element thorium (^{232}Th) is considered to be the main energy resource for the future of our civilization. Modern industry uses thorium in high-temperature and high-tech tools, but the most important property of thorium is that it can be used as fuel in nuclear reactors like uranium. However, thorium has a number of advantages compared to this element: it is 4-5 times more concentrated in the earth crust compared to uranium; extraction and enrichment of thorium is much cheaper than of the uranium; it is less radioactive; complete destruction of its waste products is possible; thorium yields much more energy than uranium. Nowadays developed countries, including India and China, started intensive work for creation of thorium nuclear reactors and intensive search for an estimate thorium reserves. It is not excluded that in the next 10 years these reactors will completely replace uranium reactors. Thorium ore mineralization is genetically related to alkaline-acidic magmatism. Unfortunately, little is known about the reserves of this element in Georgia, as the planned prospecting-exploration works of thorium were never carried out there, though there were marked 3 ore occurrences of this element: 1- in the Greater Caucasus, Kakheti segment, in the hydrothermally altered rocks of the Lower Jurassic clay-shales, where thorium concentrations varied between 51 - 3882g/t; 2 - in the eastern periphery of the Dzirula massif, in the hydrothermally alteration rocks of the cambrian quartz-diorite gneisses, where thorium concentrations varied between 117-266 g/t; 3 - in active contact zone of the Eocene volcanites and syenitic intrusive in Vakijvari orefield of the Guria region, where thorium concentrations varied between 185-428 g/t. The world class thorium deposit concentrations of this element vary within the limits of 200-300 g/t. Accordingly, on the basis of these data thorium deposits found in Georgia should be considered as perspective ore manifestations, the investigation of which should be one of the strategic interests of the State. *© 2014 Bull. Georg. Natl. Acad. Sci.*

Key words: *future energy, thorium, modern civilization, Georgia.*

According to the UN data, by the end of 2013 the world's population exceeded 7 billion, and the organization predicts that this number will double at the end of the century. At the same time, an intense process of urbanization and technological progress leads to an increased energy consumption. Experts believe that if the overall progress continues in such a pace and direction, in light of the exhaustion of hydrocarbons reserves, then the modern civilization will not have any alternatives except renewable and nuclear energy.

According to the statistical data, energy resources currently consumed by modern civilization are represented by hydrocarbons - 75-80 %, but unfortunately, taking into account current pace of hydrocarbon spending, according to the OPEC data, oil and gas reserves will run out of the Earth's crust in 40-50 years, and coal - in 100 years. At the same time, the poisonous gas CO_2, separated as a result of hydrocarbons combustion, progressively pollutes the atmosphere and have negative impact on the environment including human life.

When it comes to renewable energy (wind, solar and water energy), according to the United Nations data, despite its increase, it will amount only 23-25 % of the overall energy balance by 2020. Even with the maximum utilization of these energy resources, based on a number of objective reasons, it is impossible to satisfy at least half of the demand of modern civilization.

Based on the analysis of existing energy reserves and potential, the renewable and nuclear energy should be considered as the main energy resources for the future of our civilization. Taking into account total potential of renewable energy, according to all estimates, it can meet only 23-25% of the needs of humanity. Then it turns out that for our future energy supply, nuclear energy has no alternative. At the same time, this energy is much cheaper, which allows rapid development of technology and even in high safety conditions is environmentally most friendly. But unfortunately, all over the world all nuclear power plants work on uranium, which potentially poses a big threat to the world. For example, the tragedies of Chernobyl and Fukushima nuclear power plants are enough. But there is another radioactive element, which is far safer; can produce more energy and has more reserves than uranium in the earth crust - this is thorium.

Brief Description of Thorium. It is the 90^{th} element of the periodic table, belongs to the group of actinides and under natural conditions is presented in solid phase of ^{232}Th. As a result of its radiation, decay radioactive gases radon, radium and actinium are obtained. This element was discovered in 1882 by the Norwegian mineralogist Morten Esmark, and its identification was made by the Swedish chemist John Bertselius, who named it after Thor, the Norse god of thunder. Thorium has the highest melting (1824^0C) and boiling (4788^0C) temperatures among the chemical elements known on the Earth. Pure thorium is silvery-white element, which retains its color on the earth surface for several months, and then because of oxidation obtains the grayish-yellowish color and changes into black loose mass.

Modern industry uses thorium in high-temperature and high-tech tools. Now thorium plasma batteries are in active development, the use of which will be available for 4-7 years non-stop, without recharge. It is possible to produce batteries of different sizes, which can be used in: 1 - laptops and smaller devices, 2 - mopeds and water scooters, 3 - automobiles and trucks, 4 - ships and barges and other electrical devices. But the most important property of thorium is that like uranium it can be used as fuel in nuclear reactors [1,2,3]. However, thorium has a number of advantages compared to this element: it is 4-5 times more concentrated in the earth crust than uranium; extraction and enrichment of thorium is much cheaper companed to uranium; it is less radioactive; complete destruction of its waste products is possible; thorium yields much more energy than uranium; it is impossible to use its waste products in creation of a nuclear bomb. Because of these unique properties and currently existed difficult energetic situation thorium is considered as the main energy resource in the 3^{rd} millennium of the human civilization. Moreover, some scientists, due to the safety of this element, consider it as future green energy [4].

Natural thorium-232 is a strong energetic radioactive element, neutron energy of which can be used as fuel in nuclear reactors, including breeder reactors. The idea of using thorium as nuclear reactor fuel was initiated in the 50-s of the 20th century, but its intense study began in 1996 by the International Agency of Atomic Energy (IAEA), and in 1997 by the U.S. Department of Energy.

Ever since it became known that thorium has great energy possibility and great guarantee of safety, developed countries of the world (Germany , USA, France, England, Japan, and others) and among them India and China, started intensive work for creation of thorium nuclear reactors [5]. It is not excluded that in the next 10 years these reactors will completely replace uranium reactors.

In that direction of energy processing, India achieved the greatest success. India has already created the first reactor in the world Kakrapar-1, which uses thorium, and will be fully operated by 2016 [6]. After that the country plans construction of five more reactors. India holds 25 % of the world thorium reserves and currently envisages to produce 30% of its electricity through thorium-based reactors by 2050.

Currently, developed countries have great expectations on thorium energy, and some might say that there is made “mystery” about this element. For example, concern “Cadillac” is currently working on thorium fuel vehicle concept. The authorities of the concern say that they are trying to make an automobile, which will work on thorium energy, and 8 g of thorium will ensure its work for 100 years [7]. In fact, the final refinement of technology of atomic generators working on thorium energy needs some time, but thorium energy possibility already is clear.

Thorium minerals and deposits. Genetically thorium is related to acid magmatic rocks. Normally its content in granitoids is 4-5 g/t and it is 3-4 times more in the earth’s crust, than uranium. Its main mineral is monazite $(Ce,La,Y,Th)PO_4]$, which is met in granitoides as an accessory mineral. Besides this mineral, thorium forms the silicate mineral thorite ($ThSiO_4$), which like monazite generally represents accessory mineral of granitoides. Sometimes this mineral contains uranium, and then its formula is $(Th,U)\ SiO_4$. On the earth’s surface thorite transforms into its watery variety - thorogummite $[Th(SiO_4)\ 1\text{-}x\ (OH)\ 4x]$ and forms loose mass. One of the very rare minerals of thorium is thorianite (ThO_2), thorium oxide, which was first described as uranite in 1904. The name was given to the mineral because of a large percentage of thorium. It also contains lanthanum, cerium, praseodyum and neodyum. The mineral is met in gravels on Sri-Lanka as small, black cubic crystals with maximum size 1.5cm. The biggest crystal of thorianite is described in Madagascar with the length of 6 cm.

Thorium mineralization is genetically related to alkaline-acid magmatic sources. Thorium accumulations occur as in endogen marked so in exogenous conditions. In endogenous deposits there are distinguished: magmatic, pegmatitic, skarn and high-temperature - hydrothermal varieties. All of them are mainly related to the alkaline–acid magmatic formations. As thorium isomorphically replaces calcium, its accumulations are often marked in carbonate rocks as well. Its industrial concentration in such rocks varies within the ranges of 0.02 - 0.3 %. Thorium minerals accumulate in placers, among them the biggest one is marked in coastal zones of Indian Ocean, where the placers are enriched with monazite. Similar deposits are found in Brazil and Sri-Lanka. It is possible that magnetitic placers in Guria region coastal zone of the Black Sea also contain thorium minerals.

World reserves of thorium. Developed countries are now actively looking for thorium reserves. According to the USGS data in 2012 the current biggest reserves of thorium have been identified in India – 963,000 tons, U.S. – 440,000 tones, Australia - 300,000 tons, South Africa - 35,000 tons, Brazil - 16,000 tons, Malaysia – 4,500 tons and the rest countries – 90,000 t. This organization determined thorium reserves in the world in 2012 as 1,913,000 tons, but at the same time, according to the same source, in different countries thorium prospecting works are intensely being performed. According to Thorium Energy Alliance (TEA), there are prospected so many thorium manifestations in the US that it will be enough to power the country at its current energy level for over 10,000 years. It should be noted, that little is known about the reserves of this element in Georgia.

Thorium Ore Occurrences in Georgia.

Systematic investigation of Thorium has never been carried out in Georgia and its ore occurrences has been discovered during the investigation of gold and other ore elements. In Kakheti segment of the Great Caucasus, while prospecting the gold mineralization, our group occasionally discovered industrial accumulations of thorium [8, 9, 10]. Also, within the limits of Dzirula massif, while prospecting gold, we fixed high concentrations of thorium. In addition, in the 90-s of the 20th century, in Guria region, while prospecting uranium a group of Geology Department fixed high concentrations of thorium at several areas [11], but as thorium was not object of interest in that moment, nobody paid any attention to it.

Thorium occurrences in Kakheti segment of the Great Caucasus. Kakheti segment is located in the eastern part of the southern slope of the Great Caucasus. It is traced over 120 km from the Iori and Alazani rivers dividing till the Azerbaijan border as a 20-35 km width zone, with an area of 3400 km^2. The river Alazani sources and its left tributaries – Makhvali, Stori, Didi Khevi, Lopota, Chelti and others outcrop the Kakheti segment. The region is mainly built of intensely folded Lower-Middle Jurassic shales [12], sandstones and extrusive nappes of dacite-andezite-bazalt composition. The whole complex of sedimentary rocks is crossed by numerous intrusive bodies of different thickness and composition. According to geophysical research data, the Great Caucasus Kakheti segment sedimentary formations are located on of a thin crust the transitional type [13]. We share the given version of the region's deep construction scheme, as the whole spectrum of magmatic activity represents a trustful argument.

More than hundred various quartz-pyrite-pyrrhotite and copper-polymetallic ore mineralization are observed in the Caucasus Kakheti segment. These ore mineralization form disseminations, veinlets, veins and massive bodies. Preferentially, there are formed veinlet type of ores, which sometimes transit into massive ores. Ore mineralization is preceded by a hydrothermal process and silicification when quartz-sericite-albite and quartz-sericite-epidote-carbonaceous associations are formed.

Among Kakheti mineralized areas the Stori Valley occurrences, which crosses the Southern slope of the Greater Caucasus perpendicularly deserves most special interest. Here the Lower Jurassic sedimentary rocks are intensively broken at about 4 km distance, experienced hydrothermal alteration - silicification, sericitization, carbonatization, and sulfide mineralization. The process is so intense that recognition of source rocks is often impossible.

In 2011, within the project of Shota Rustaveli National Scientific Foundation, providing the evaluation of Caucasus Kakheti region prospectives on gold, we were able to analyze 13 samples from the river Stori gorge and 7 samples from Makhvali river gorge in Vancouver Acme Analitical laboratory on ICP-ES device (Canada) by 1F15 method. The results obtained turned out to be a surprise for us, as anomalously high concentrations of thorium and bismuth were defined in these samples [8, 9, 10]. In particular, thorium and bismuth concentrations in one carbonaceous quartz-pyrite-pirrhotitic vein were anomalously high, whereas uranium concentrations were within the clark everywhere. Within one mineralized vein there was fixed 3842 g/t of thorium, and 40806 g/t - bismuth, which is obviously a high industrial content. As for the other samples, high concentrations of thorium and bismuth were also observed. Thorium content in these samples is rather high and varies in the range of 51 g/t to 230 g/t. Taking into account the fact that in world-class deposits thorium content ranges between 200-300 g/t [14], the thorium potential in the Stori river gorge is apparent. As the project was concerned on detection of high gold concentrations we did not have the opportunity to study this interesting mineralization in detail.

Dzirula Massif. The Dzirula massif is exposed in the central part of the Bleak Sea-Central Transcaucasian Terrane [15] and occupies nearly 1200 km^2 at the current erosion level. It is mainly constructed by Neoproterozoic plagiomigmatites, crystalline schists, and quartz-dioritic gneisses and ophiolites (gneiss-migmatite complex); Cambrian tonalities and granodiorites; Late Paleozoic anatectic microcline granites; and Late Triassic orthoclase gabbros (Rikotites). Most of the Dzirula massif is composed of the gneiss-migmatite complex. Its protolith was represented by crystalline schists, plagiogneisses and plagiomigmatites, which underwent the Grenvilian regional metamorphism [16].

During the mid-Jurasic tectonic-thermal activation period diorite composition powerful pluton (60 km^2) was intruded into the quartz diorite gneiss of the Eastern part of Dzirula massif, which is known in geological literatute as Khevi intrusive and which caused active hydrothermal changes of the cantry rocks [17]. In the range of this zone in river Nadaburi gorge we fixed an anomalically high composition of thorium fixed by us.

Near the village Nadaburi the Cambrian quartz-diorite gneisses undergo intensive hydrothermal alteration and sulfide mineralization. Sulfide minerals are represented by pyrite and pyrotite. There were gathered 12 point tests of these rocks for gold analysis along the gorge with 180 m intervals. Chemical analysis of the tests were done in the same laboratory using the same method as in the case of Kakheti sample. Thorium and bismuth high composition was fixed in 5 out of 12 sample tests, where thorium composition was in 117 g/t to 266g/t range. As to bismuth, it was from 143 g/t to 2470g/t. We can see that this area is characterized by high mineralization of thorium.

Guria Region of the Lesser Caucasus Achara-Trialaeti Trust-Fold Zone. After mobile theory the Achara-Trialeti folded system of the Lesser Caucasus is considered as a volcanic island-arc inner rift trough [18]. Guria region occupies NW part of this zone and is mainly built up by Cenozoic (Paleogene-Neogene) formations. Guria ore field itself is built up by Eocene volcanogenic-sedimentary and intrusive formations. The oldest stratigraphic unit in Guria region is Middle Eocene Nagvarevi suite, which constructs arch part of Sairme anticline. It is represented by bedded, medium clastic basaltic tuffs and carbonates.

The most thickest intrusive formation in Guria region is Vakijvari syenite pluton. It is located in the central part of the region, near the Vakijvari village and represents one of the largest plutonic body of the Achara-Trialeti fold-thrust belt. The biggest outcrop of this complex is exposed in the gorge of the river Bjuja, which occupies an area of 15 km^2 on the modern erosional level. Comparatively smaller bodies crop out in the gorges of the tributaries of this river. Erosional outcrops of the mentioned bodies are separated from each other by Middle Eocene volcanogenic-sedimentary country rocks (dated faunistically).

As for the age of this intrusion rocks, it was recently dated by U-Pb method in the Department of Geosciences of Taiwan National University. It corresponds to 46.77+0.81 Ma (Middle Eocene). Based on this age, it turns out that volcanic activity was at once followed by plutonic activity, though so far it has been considered that the injection of plutonic magma took place in Upper Eocene. Vakijvari intrusive complex is mainly of subalkaline syenetic composition comprising pyroxene–biotite and hornblende-bearing varieties, though biotite-pyroxene monzonites are observed as well. These are mainly coarse-grained rocks, which contain pyroxene (egirin-avgit), horn blende, potassium feldspar, oligoclase, biotite and magnetite. Accessory minerals are apatite and sphene. Pyroxene–biotite syenites are the major part of Vakijvari intrusive complex consisting mainly of alkaline rocks. It should be mentioned that in contact with volcanogenic-sedimentary rocks of Vakijvari intrusive complex, strong postmagmatic hydrothermal alteration zones are developed. On some areas of these zones there occur ore mineralization, forming Vakijvari orefield.

Vakijvari orefield (70 km^2) within their boundaries are represented by 10 gold containing ore occurrences, which could be united into four groups according to their spatial position and composition. In particular, Shemokmedi, Pampaleti, Vakijvari and Gomi. The results of analyses of conducted geological activities in Vakijvari ore field show that gold-bearing ore manifestations are singled out quartz-copper-polimetallic, iron ore-pegmatitic, sulphur-pyrite, copper-molybdenum-porphyry and low sulfidation ore mineralization. All ore occurrences in this ore field are spatially and genetically related to endo- and exocontact areas of Vakijvari intrusive complex.

In the 80s of the 20th century in ore manifestations of Vakijvari group special investigations of radioactive elements were carried out. Field work held gamma-ray profiling by means of radiometer CPR-68 [11]. In this ore field an anomalous content of uranium have not been found, though three significant anomalies of thorium were exposed: Nasakhlebi-1 (Th-185 g/t), Nasakhlebi-2 (Th-237 g/t) and Chkhikva (Th-428 g/t). The sample analyses were done in the Russian 'Koltsovgeologia' laboratory. No one was interested in further study of these anomalies, because at that time there was a need for uranium, and thorium was not considered as radioactive raw material.

Discussion. Thus, as we see, in different regions of Georgia (Kakheti segment of the Great Caucasus Southern slope, Dzirula massif and in Guria region of the Achara-Trialeti Thrust-Fold Zone) thorium concentration is clearly raised. As we mentioned above, according to modern standards of the world class thorium deposit, thorium concentration varies within the limits of 200-300 g/t. Correspondingly, relying on these data thorium ore occurrences of Georgia should be treated as prospective objects, therefore it is necessary to investigate them in detail.

Unfortunately, Department of Geology in Georgia has been canceled and there is no other organization in the state who can emphasize the importance of this strategic raw material and fund and conduct the prospecting and exploration works. Furthermore, in Georgia there exist preliminary data on significant mineralization of this element. In addition, geological settings of the areas, where thorium occurrences were fixed, give theoretical basis on possible accumulation of practical importance of thorium ores. Besides the Black Sea magnetite sand, which is transported from Vakijvari ore field, can possibly contain thorium composition minerals.

Conclusion. If we sum up the research carried out by us, it will be clear that thorium energy and ecological characteristics as compared to uranium has far more important advantages, namely, it is concentrated in the Earth crust 4-5 times more than uranium; extraction and enrichment of thorium is much cheaper compared to uranium; it is less radioactive; complete destruction of its waste is possible; thorium yields much more energy than uranium; usage of its waste products is impossible in creation of a nuclear bomb. Because of these unique properties and currently existed difficult energetic situation thorium is considered as the main energy resource in the 3rd millennium of the modern civilization.

Because of thorium energy advantages and its relatively ecological safety it is indisputable that our civilization made a great mistake choosing uranium as nuclear fuel on the way of nuclear energy development and not thorium. It appears that using thorium the mankind is now choosing a correct way of nuclear energy development that will significantly change modern civilization development chances and quality of life.

As to thorium ore manifestations found in Georgia, they should be treated as prospective objects taking into consideration the situation in the world concerning the concentration of this element in the deposits. At the same time, as a result of theoretically well-calculated geological search, it is possible to find new important thorium ore manifestations. Generally, we consider that complex investigation of thorium should be included into the sphere of strategic interests of the state. At this stage it might be difficult for the country to provide a full scale exploration work and geological search-investigation, but still, it should manage not to issue licenses on the already known territory with thorium ore occurrence.

გეოლოგია

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ილიას სახელმწიფო უნივერსიტეტის საინჟინრო ფაკულტეტი, თბილისი

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ნახშირწყალბადების მარაგების ამოწურვის ფონზე, თანამედროვე ცივილიზაციის სასიცოცხლოდ მნიშვნელოვან პრობლემას ახალი ენერგორესურსების ძიება წარმოადგენს. ამჟამად მომავლის ძირითად ენერგეტიკულ რესურსად ექსპერტთა მიერ განახლებადი და ბირთვული ენერგია განიხილება. თუ გავაანალიზებთ ჩვენი ცივილიზაციის მიერ ამჟამად მოხმარებულ ენერგიაში განახლებადი ენერგიის წილს (18–20%) და მის პოტენციალს (25–28%), მაშინ ცხადი გახდება, რომ კაცობრიობის მომავლის ენერგოუზრუნველყოფაში ბირთვულ ენერგეტიკას ალტერნატივა არ გააჩნია. თუმცა, მკვლევარები ამჟამად მომავლის ძირითად ბირთვულ ენერგორესურსად არა ურანს, არამედ რადიაქტიურ ელემენტს, თორიუმს (^{232}Th) განიხილავენ. თორიუმს თანამედროვე მრეწველობაში იყენებენ მაღალტემპერატურულ და მაღალტექნოლოგიურ ხელსაწყოებში. ამჟამად ინტენსიურად მიმდინარეობს მისი პლაზმური ბატარეების შექმნა, რომელთა მუშაობის ხანგრძლივობა დამუხტვის გარეშე შესაძლებელი იქნება 4–7 წელი, მაგრამ ამ ქიმიური ელემენტის ყველაზე მნიშვნელოვანი თვისება ისაა, რომ იგი ურანის მსგავსად შესაძლებელია გამოყენებულ იქნეს როგორც საწვავი ბირთვულ რეაქტორებში. თუმცა, თორიუმს ამ ელემენტთან შედარებით გააჩნია მთელი რიგი უპირატესობები: დედამიწის ქერქში იგი 4–5 ჯერ უფრო მეტია, ვიდრე ურანი; მოპოვება და გამდიდრება ურანთან შედარებით გაცილებით იაფია; არ მოითხოვს იზოტოპურ სეპარაციას; ნაკლებად რადიაქტიურია; შესაძლებელია მისი ნარჩენების სრული განადგურება; გაცილებით მეტ ენერგიას გამოიმუშავებს ვიდრე ურანი; მისი ნარჩენების გამოყენება ატომური ბომბის შესაქმნელად შეუძლებელია. ამჟამად მსოფლიოს განვითარებული ქვეყნები, და მათ შორის ინდოეთი და ჩინეთიც, ინტენსიურად ამუშავებენ თორიუმზე მომუშავე ბირთვულ რეაქტორებს. ვარაუდობენ, რომ ამ რეაქტორებმა, უახლოეს 10 წელიწადში, შესაძლოა მთლიანად ჩაანაცვლოს ურანის რეაქტორები. თორიუმის გამადნებები გენეტურად ტუტე-მჟავე მაგმატიტებთანაა დაკავშირებული, რომელთა დაგროვებები აღინიშნება როგორც ენდოგენურ, ისე ეგზოგენურ პირობებში. განვითარებული ქვეყნები ინტენსიურად ეძებენ და ითვლიან ამ რადიაქტიური ელემენტის რეზერვებს, რომლის ყველაზე დიდი მარაგი ინდოეთს გააჩნია (963000 ტონა). საქართველოში თორიუმის რეზერვების შესახებ არავითარი ცნობები არ არსებობს, რადგანაც არასოდეს ჩატარებულა მისი გეგმაზომიერი ძებნა-ძიება, თუმცა ჯერჯერობით აღინიშნება ამ ელემენტის შემთხვევით მიკვლეული 3 მადანგამოვლინება: 1. კავკასიონის კახეთის სეგმენტში, სადაც

ჰიდროთერმულად გადამუშავებულ ქვედაიურულ თიხაფიქლებში, თორიუმის შემცველობა 50 გ/ტ–დან 3880 გ/ტ–მდე ფარგლებში მერყეობს; 2. ძირულის კრისტალური მასივის აღმოსავლეთ პერიფერიაზე, მდ. ნადაბურის ხეობაში ჰიდროთერმულად შეცვლილ კამბრიულ კვარც-დიორიტულ გნეისებში, სადაც თორიუმის შემცველობა 117 –266 გ/ტ ფარგლებში დაფიქსირდა (ამ არეალიდან სინჯების ქიმიური ანალიზი ჩატარდა კანადის AcmeLab–ის ლაბორატორიაში ICP-ES დანადგარზე, 1F15 მეთოდის გამოყენებით); 3. გურიის რეგიონის ვაკიჯვრის მადნიან ველში, შუაეოცენური ვულკანიტების და სიენიტური ინტრუზივის კონტაქტის ზონებში თორიუმის შემცველობა 185–428 გ/ტ–ს ფარგლებშია (ანალიზები ჩატარდა რუსეთის „კოლცოვგეოლოგიის" ლაბორატორიაში). თანამედროვე მოთხოვნილების მიხედვით მსოფლიო კლასის თორიუმის საბადოებში ამ ელემენტის შემცველობა საშუალოდ 200–300 გ/ტ–ს შეადგენს. შესაბამისად, ამ მონაცემების ფონზე საქართველოში დაფიქსირებული თორიუმის მადანგამოვლინებები მნიშვნელოვან წარმონაქმნებად უნდა განვიხილოთ, რომელთა შემდგომი შესწავლა და განკარგვა სახელმწიფოს სტრატეგიული ინტერესების სფეროში უნდა მოექცეს.

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