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Thorium Resources and their Energy Potential in Georgian Republic, the Caucasus

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Abstract

Because of its unique properties thorium is considered as the main energy resource in the 3rd millennium. In Georgia are detected four Thorium ore occurrences: 1 - In the Sothern slope of the Greater Caucasus (Th con. 51 g/t - 3882 g/t), 2 - In the Dzirula massif (Th con. 117 g/t - 266 g/t), 3 - In Vakijvari ore field (Th con.185 g/t - 1600 g/t), 4 - In the Black Sea magnetite sands (Th con. 200 g/t - 450 g/t). Based on these data Georgian thorium ore occurrences should be treated as potential resources.

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Keywords: The Caucasus, Georgia, thorium ore, the magnetite Sand;

1. Introduction

According to the UNESCO data 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 is on going, which leads to an increase in total energy demand and consumption. As is well known energy resources, currently consumed by modern civilization, are represented by hydrocarbons - 78-80 %, however these reserves are exhausting. At the same time, the gas CO_2, separated because of hydrocarbons combustion, intensely pollutes the atmosphere and have significantly negative impact on the environment, including human life.

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In light of these challenges, search of new energy resources is vital importance problem for the 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 the total potential of renewable energy, according to all estimates, only 23-25% of it can meet the needs of humanity, then it turns out that for our future energy supply, nuclear energy has no alternative. Unfortunately, all over the world all nuclear power plants work on uranium, which potentially poses a big threat because of its properties. However, thorium is that like uranium and it can be used as fuel in nuclear reactors. However, thorium has a number of advantages compared to the Uranium. It is concentrated in the earth crust 4-5 times more than uranium; extraction and enrichment of thorium is much cheaper than uranium's; it is less radioactive; complete destruction of its waste products is possible; thorium yields much more energy than uranium. Because of unique properties and currently existed difficult energetic situation, thorium is considered as the main energy resource in the 3rd millennium of the human civilization [1]. Moreover, some scientists, due to the safety of this element, consider it as future green energy [2].

Unfortunately, government of Georgia does not pay any attention to thorium energy potential, also, systematic investigation has never been carried out in the country, however its geological construction creates precondition of possible existence of thorium considerable deposits in the earth crust.

Available information on thorium occurrences of Georgia is collected and analyzed in the presented paper, which, in our opinion should be of great interest for researchers of this important energy element deposits.

2. Geological Framework of Georgia

The Caucasus represents a collisional orogen that formed along the Eurasian North continental margin and extends over 1200 km from Caspian to Black Sea. Currently it represents the Tethyan segment connecting the Mediterranean and Iran-Himalayan orogenic belts, between the Gondvana-derived Arabian plate and East European platform. Three major geological units are distinguished in its construction: the Greater and Lesser Caucasian mobile belts and the Transcaucasus microplate [3]. According of the terrane analyses the Greater Caucasian, Black Sea-Central Transcaucasian, Baiburt-Sevanian (Lesser Caucasian) and Iran-Afghanian terranes are identified in the Caucasian segment (Fig. 1). They are separated from each other by ophiolitic suture zones or powerful tectonic faults which in geological past represented island arcs or microcontinents [4]. The territory of Georgia covers southern part of the Greater Caucasus, the Transcaucasus and northern part of Lesser Caucasus that is why is characterized by a complex geological structure.

The structure and geological history of the Caucasus are largely determined by its position between the still-converging Eurasian and Africa-Arabian lithospheric plates, within a wide zone of continental collision. During the Late Proterozoic -Early Cenozoic, the region belonged to the Tethys Ocean and its Eurasian and Africa-Arabian margins where there existed a system of island arcs, intra-arc rifts and back-arc basins characteristic for the pre-collisional stage of its evolution of the region [5].

Modern research shows that in formation of the Caucasus orogen pre-Mesozoic crust significant role was played by Gondvana-derived micro-plates, which formed after the destruction of the Gondvana southern edge in the Ordovician period. Large part of them started moving towards the North and accreted at the S-E edge of the Euro-Asia continent. Building the skeleton, this underwent significant thermal recycling and transformation in composition and gradually formed the modern crust of the Caucasus orogen. Despite the multiple tectonic, metamorphic and thermal processing (Variscan, Cimmerian and Alpine), they have still preserved Gondvanian relicts, which are considered as pre-Variscan "crystalline basement" [3]. The complex geological and isotopic (Sm-Nd, U-Pb, Rb-Sr and ^{40}Ar-^{39}Ar systems) data of these relicts, enabled us to restore the history of their evolution. The Caucasus Carboniferous granitiods (330 - 305 Ma; U-Pb, Rb-Sr and ^{40}Ar-^{39}Ar age) contain numerous inherited zircons of a major Hf isotopic age distribution at ca. 700-500 Ma and strongly various Hf isotope composition, indicating an affiliation to magmatic activities that produced the juvenile Arabian-Nubian Shield crust and reworked Neoproterozoic materials in the Northern Gondvana [6]. According to our data, Gondvana-Derived relicts were organically involved in the processes of the Caucasus orogen formation and they have created vertically and horizontally accretion skeleton, which partial conversion (metamorphism, ultrametamorphism, recycling), basement of the Caucasus orogen was formed, at the southern edge of the East European platform. These rocks are dated as pre-Jurassic Dzirula, Khrami, Loki, Akhum, Asrikchai and Takhkunyats massifs.

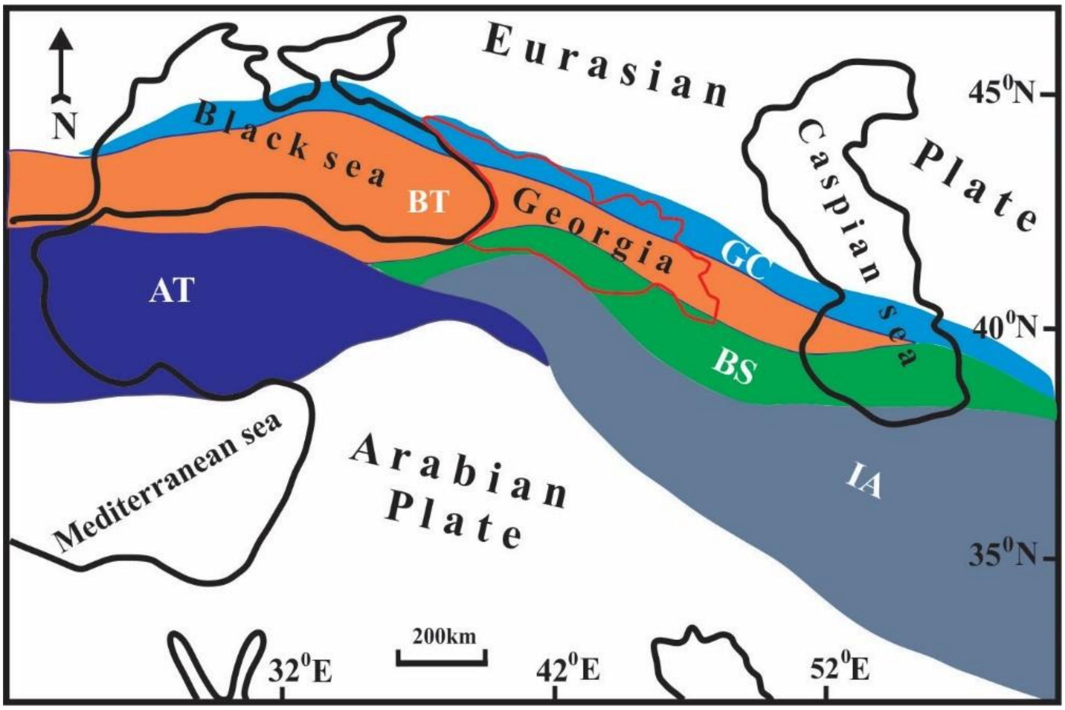

Fig. 1 .Simplified Geological Scheme of the Caucasus and adjacent area on the basis of the terrane analysis, adapted according to Gamkrelidze (1997). Terranes: GC-Greater Caucasian, BT-Black Sea-Central Transcaucasian, BS-Beiburt-Sevanian (Lesser Caucasian), IA-Iran-Afganian, AT - Anatolian.

Widespread emplacement of microcline granite plutons along the active continental margin of southern Eurasia during 330-305 Ma occurred above a north-dipping Palaeotethyan subduction zone. However, Variscan and Cimmerian-Early Alpine events did not lead to the complete closing of the Palaeozoic Ocean.

The Mesozoic Tethys in the Caucasus was inherited from the Palaeotethys. In the Mesozoic and Early Cenozoic, the Great Caucasus and Transcaucasus represented the Northtethyan realm the southern active margin of the Eurasia lithospheric plate. The Oligocene and Neogene basins situated within the Transcaucasian intermontane depression mark the syn- and post-collisional evolution of the region; these basins represented a part of Paratethys and accumulated sediments of closed and semi-closed type.

The final collision of the Africa-Arabian and Eurasian plates and formation of the present-day intracontinental mountainous edifice of the Caucasus occurred in from the Late Miocene (ca. 9-7 Ma) to the end of the Pleistocene. In this period in the central part of the region, volcanic eruptions of subaerial conditions occurred simultaneously with the formation of molasse troughs.

Quaternary deposits in Georgia are distributed very irregularly. These consist of river and Black Sea terraces (among them black sands), moraines of three glacial periods, and a volcanic formation in the form of volcanic cones and lava flows (in the Greater Caucasus and on the Samtskhe-Javakheti volcanic province. There are also vast accumulation plains in intermountain areas.

3. Thorium Ore Occurrences of Georgia

Systematic investigation of Thorium has never been carried out in Georgia and its ore occurrences have 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 [7]. Also within the limits of Dzirula massif, again while prospecting gold; high concentrations of thorium were investigated. In addition, in the 90 - s of the 20th century, in the Vakijvari ore field, of the Guria region, while prospecting uranium a group of Geology Department researched high concentrations of thorium at several areas [8], but as thorium was not object of interest in that moment, nobody paid any attention. The black sand (magnetite sand) of the Black Sea coastal zone have been studied by us, where high concentrations of thorium have been detected (Fig. 2).

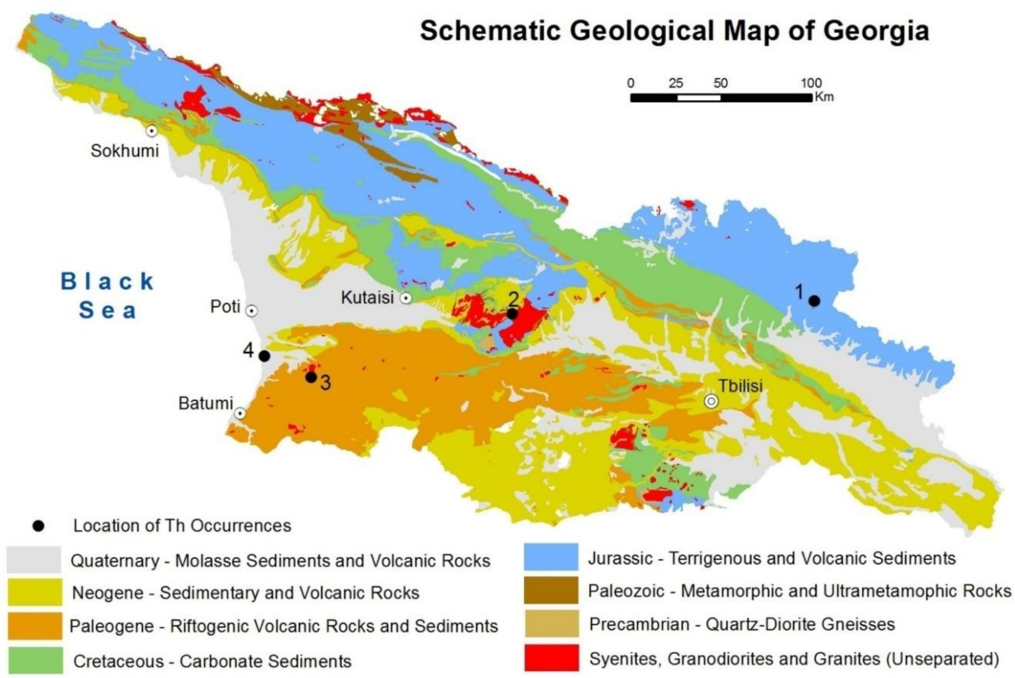

Fig. 2. Schematic Geological Map of Georgia, adapted according to Gamkrelidze [9], with location of Th ore occurrences. 1- Kakheti segment, 2- Dzirula massif, 3- Vakijvari ore field, 4- Guria Black Sea sands.

3.1. Thorium Ore Occurrences in Kakheti Segment of the Greater Caucasus

Kakheti segment is located in the eastern part of the southern slope of the Great Caucasus and is traced over 120 km from the Iori and Alazani rivers dividing till the Azerbaijan border as a 20-35 km width zone. The region is mainly built of intensely folded Lower-Middle Jurassic shales, 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 transitional type thin crust [10].

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 vein let type 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 deserves most special interest, which crosses the Southern slope of the Greater Caucasus perpendicularly. Here the Lower Jurassic sedimentary rocks are intensively broken at about 4 km distance, experienced hydrothermal alteration - silicification, sericitization, carbonatization, and sulfide mineralization (Fig. 3).

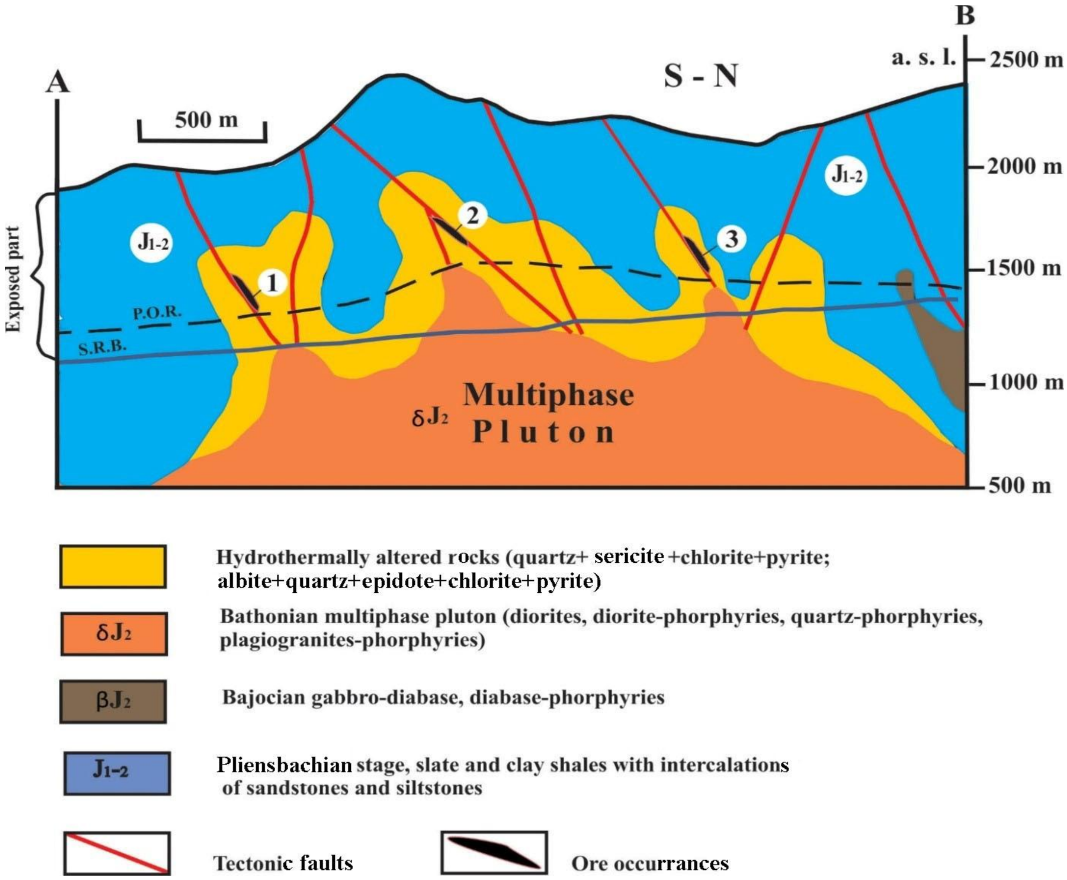

Fig. 3. Schematic cross section (A-B) of the Stori canyon hydrothermal altetation zone. (A=N $42^0 12^1 968^{11}$, E $45^0 29^1 079^{11}$; B = N $42^0 13^1 953^{11}$, E $45^0 29^1 079^{11}$). Mineral occurrences: 1 - Bendena quartz-pyrite-pirrhotitic zone , 2 - Gelia quartz-pyrite-pirrhotitic zone , 3 - Stori quartz - Thorium - bismuth zone, (P.O.R. - Phshaveli - Omalo road; S.R.B. Stori River bed).

In 2011, within the project of Shota Rustaveli National Scientific Foundation, providing the evaluation of Caucasus Kakheti region prospective on gold, we were able to analyze 18 samples from the river Stori gorge and 7 samples from Makhvali river gorge in Vancouver Acme Analytical laboratory by ICP-ES method (Canada). The results obtained turned out to be a surprise for us, as anomalously high concentrations thorium and bismuth were defined in these samples [6]. In particular, thorium and bismuth concentrations of the Stori canyon carbonaceous quartz-pyrite-pirrhotitic zone were anomalously high, whereas uranium concentrations were within the Clark everywhere. Within the one mineralized quartz- plagioclase vein was provided as 3842 g/t thorium, and 40806 g/t -

bismuth, which is obviously a high content. As for the other samples, high concentrations of thorium and bismuth were observed also. 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 [11], the thorium potential in the Stori rivergorge is apparent. Because the project was concerned on detection of high gold concentrations we have not been given the opportunity of detail study of thisinteresting mineralization.

3.2. Thorium Ore Occurrences in Dzirula Massif of the Transcaucasus Microplate

The Dzirula massif is exposed in the central part of the Transcaucasus microplate and occupies nearly 1200 km^2 at the current of 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 [5].

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 country rocks. In the range of this zone in river Nadaburi gorge anomalically high compositions of thorium were investigated.

Near the village Nadaburi pre-Cambrian quartz-diorite gneisses undergo intensive hydrothermal alteration and sulfide mineralization. Sulfide minerals are represented by pyrite and pyrrhotite. 12 point tests of these rocks have been gathered for gold analysis along the gorge with 180 m intervals. Chemical analysis of the tests were done in the same laboratory and using the same method. Thorium and bismuth high composition was fixed in 7 out of 12 sample tests, where thorium composition is in 117 g/t to 266 g/t range. As to bismuth it is from 143 g/t to 2470 g/t. It is obvious that this area is characterized by high mineralization of thorium as well as bismuth.

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3.3. Thorium Ore Occurrences of the Vakijvari Ore Field of Guria Region

Guria region is located in the Achara-Trialaeti Trust-Fold Zone of the Lesser Caucasus, which after mobile theory is considered as a volcanic island-arc inner rift trough. It is occupies NW part of this zone and is mainly built up by Paleogene formations. The oldest stratigraphic unit in region is Middle Eocene Nagvarevi suite, which 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 theAchara-Trialeti fold-thrust belt. The biggest outcrop of this complex is exposed in gorge of the river Bjuja, which occupies an area of 15 km^2 on the modern erosion level. Comparatively smaller bodies crop out in the gorges of the tributaries of this river. Erosion outcrops of the mentioned bodies are separated from each other by Middle Eocene volcanogenic-sedimentary country rocks.

Vakijvari intrusive complex (46.77±0.81 Ma, U-Pb age) is mainly of subalkaline syenitic composition comprising pyroxene - biotite and hornblende-bearing varieties, though biotite-pyroxene monzonites are observed. These are mainly coarse-grained rocks, which contain pyroxene (egirin-avgit), hornblende, potassium feldspar, oligoclase, biotite and magnetite. Accessory minerals are apatite and sphene (Fig.4). Pyroxene - biotite syenites are constructed the major part of Vakijvari intrusive complex are mainly 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 ore mineralization occurrences are observed, forming Vakijvari orefield (Fig. 4).

Vakijvari orefield (70 km^2) within their boundaries are represented by four ore occurrences, 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-polymetallic, iron ore-pegmatitic, sulphur-pyrite, copper-molybdenum-porphyry and low sulfidation ore mineralization (Chkhikvishvili et a., 1993). All ore occurrences in this ore field are spatially and genetically related to endo- and exocontact areas of Vakijvari plutonic complex.

In the 80's of the 20th century in Vakijvari ore field special investigations of radioactive elements were carried out in pyrite-chalcopyrite-magnetite lodes and massive ore (Fig. 4). Investigations work was held gamma-ray profiling by means of radiometer CPR-68 [8]. In this ore field anomalous contents of uranium have not been found, though five significant anomalies of thorium were exposed: Chachuas Gele (Th concentrations vary between 220 g/t - 458 g/t), Nasakhlebi - 1 (Th - between 185 g/t - 1600 g/t), Nasakhlebi - 2 (Th - between 237 g/t - 374 g/t), Chkhikva ((Th - between 428 g/t - 630 g/t) and Qorbuda (Th - 330 g/t - 840 g/t). The sample analyses were performed in the Russian, Kislavodsk "Koltsovgeologia" laboratory. There was not any interest in further study of these anomalies, because at that time there was a need for uranium, and thorium had not been discussed as radioactive raw material.

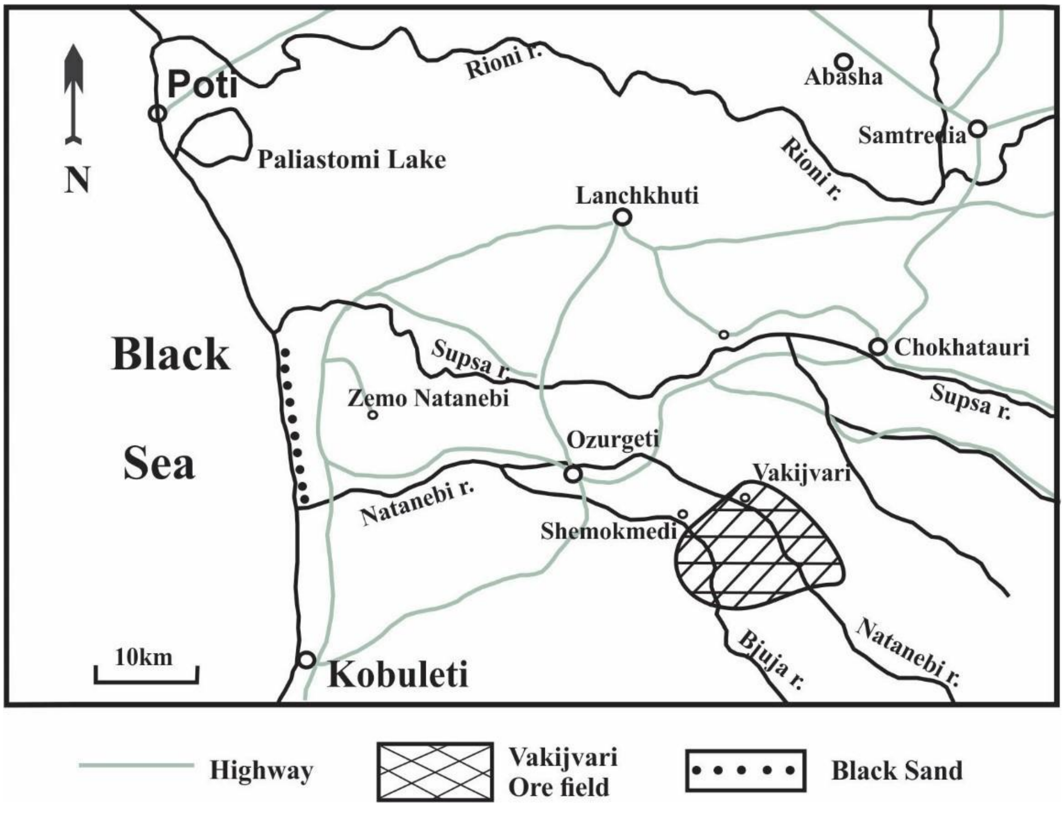

Fig. 4. Schematic map of Guria region with location Black sands and Vakijvari Ore field.

3.4. Magnetite Sands of the Black Sea Guria Region Coastal Zone

The river Natanebi and its tributaries intensely wash Vakijvari orefield (Fig.4), including iron ore-pegmatite association, and the eroded material is deposited along the Black Sea Guria coastal zone (Fig. 5), from the Natanebi river confluence till the Supsa river confluence. The length of the coast is 15 km and width - of 60 - 120 m. These sands at the coastal zone form famous, so-called Ureki and Shekvetili healing beaches, which treat joint diseases. It is possible that the healing properties of the sand are caused by its weak radioactivity, which is elevated by thorium concentration.

Twenty samples of the magnetite sands have been taken and thorium content has been detected by X-ray fluorescence spectrometer (ELVAX-SIP01). The analysis showed that concentration of this element in the sands ranges between 480 - 220 g/t interval, and it decreases from the Natanebi river confluence towards the Supsa river confluence. This is probably due to a decrease of magnetite material share in the sands, because the river Natanebi transports these sands to the Supsa river direction. This also allows us to assume that thorium is concentrated in magnetite in form of monazite inclusions, similar to Brazilian and Indian magnetite sands.

Fig. 5. Magnetite Sands of the Black Sea Guria Region, Shekvetili Beach.

4. Conclusion

Finally, in different regions of the Georgia (Kakheti segment of the Greater Caucasus, Dzirula massif of the Transcaucasus and Guria region of the Lesser Caucasus) thorium concentration is clearly raised. As mentioned above, to modern standards of the world class thorium concentration is varying 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 in fact has been canceled and there is no other organization in the state that emphasizes the importance of this strategic raw material and fund and conduct the prospecting and exploration works. At the same time, geological settings of the areas, where thorium occurrences were observed, give a theoretical basis on possible accumulation of industrial importance thorium ores. As a result of theoretically well-calculated geological search work, it is possible to discovery new important thorium ore occurrences. Generally, we consider that complex investigation of thorium resources should be included into the sphere of strategic interests of the Georgian state. At this stage it may not be possible for the country to provide a full scale exploration work and geological search-investigation, but should still manage not to issue licenses on the territory with thorium ore occurrence areas already known.

Acknowledgements

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References

[1] Kazimi (2003) “Thorium fuel for nuclear energy”, American Scientist 91 (2003): 305-313.
[2] Martin (2009) “Uranium is So Last Centure – Enter Thorium , the New Green Nuke”, Weird Magazine, Dec. 21.(Available at www.wierd.com/magazine/2009/12ff_new_nukes)
[3] Okrostsvaridze, Tormey (2013) “Phanerozoic Continental Crust Evolution of the Inner Caucasian Microplate”, IUGC Journal Episodes” 36, 1 (2013): 17-23.
[4] Gamkrelidze (1997) “Terrane of the Caucasus and adjacent areas”. Bulletin of the Georgian National Academy of Sciences, 155, 3 (1997): 75-81.
[5] Gamkrelidze, Shengelia (2005) “Precambrian-Paleozoic Regional Metamorphism, Granitoid Magmatizm and Geodinamics of the Caucasus.” M: Scientific World, (2005): 458.
[6] Okrostsvaridze, Chung, Tormey, Bluashvili (2016) “Gondvana-Derived Relics in the construqtion of the Caucasus Collisional Orogen.“ Abst. SEG Conference
[7] Okrostsvaridze, Akimidze, Bluashvili (2011) “The First Data on Industrial Concentration of Thorium and Bismuth in Hydrothermally Altered Lover-Jurassic Clay-Shales of the Stori Canyon (Greater Caucasus)”, Bulletin of the Georgian National Academy of Sciences, 5, 2 (2011): 76-82.
[8] Chkhikvishvili, Bandzeladze, Tokhadze, Kakabadze (1993) “Report of gold exploration-revision work during 1968–1972.” Fund materials of Georgian geological department, Tbilisi (1993): 173.
[9] Gamkrelidze (Edit) (2003) Geological map of Georgia, Scale 1:500 000.
[10] Philip, Cisternas, Gvishiani, Gorshkov (1989) “The Caucasus: an actual example of the initial stages of continental collision” Tectonophysics (1989): 161, 1–2: 1-21.
[11] Gosen, Gillerman, Armbrustmacher (2009) “Thorium Deposits of the United States – Energy Resources for the Future?” USGS Circular 1336 (2009): 21. (available at URL http://pubs.usgs.gov/circ/1336) (2009).