Petrographic-geochemical characteristics of granitoids and their epigenetic alteration products in paleovalley fields (Vitim uranium-ore site)

E S Kuznetsova, V A Domarenko, I A Matveenko

Tomsk Polytechnic University, 30 Lenin Avenue, Tomsk, 634050, Russia

E-mail: usoltseva_es@mail.ru, viktor_domarenko@ mail.ru, mia2046@yandex.ru

Abstract. The study describes the results of the mineral and element composition of granitoids in basement and weathering crust of Khiagdinsk ore field in Vitim uranium ore site. It has been stated that granitoids in basement consist of leucocratic biotite granite of subalkaline group. The major rock-forming, accessory (apatite, zircon, sphene (titanite), magnetite, monazite, xenotime), and uranium-bearing minerals have been determined. Weathering crust is composed of unlithified or weakly lithified sediments, among which sandy and sandy medium gravel deposits have been distinguished in terms of mineralogical and granulometric texture. High radioactivity of granitoids was revealed in thorium-uranium basement and natural uranium. The combination of the specified factors presupposes that granitoids of Vitim uranium ore site may be a source of uranium in the fields of the paleovalley type.

1. Introduction

The interest in studying uranium and thorium in granitic rocks started in the 1950's due to two facts: with understanding the fact that these rocks have, on average, higher uranium and thorium contents than any other rock types and weathering of granitic rocks may be a source of uranium in some deposits [1]. For example, as early as in 1969 Rosholt and Bartel showed a clear relationship of uranium deposits and surrounding outcrops of granitic rocks [2].

Specialized survey of uranium within Vitim plateau by Sosnov expedition began in 1947. Khiagdinsk ore field is located in the Republic of Buryatia, Central Transbaikal. Ore field includes 8 uranium deposits of paleovalley type (Khiagdinsk, Vershinnoye, Istochnoye, Namaru-Koretkonde, Kolichikan, Tetrakhskoye, Dybryn, Gilindinskoye) (fig. 1).

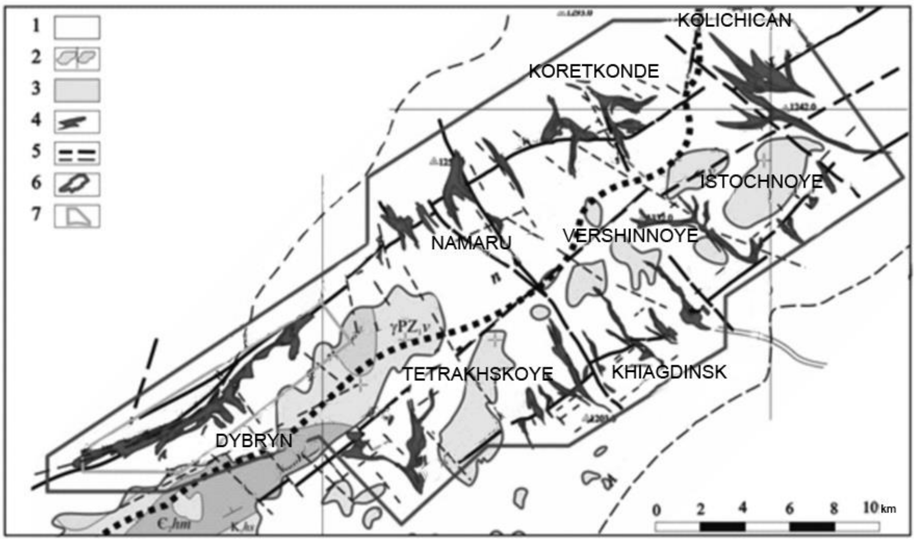

Figure 1. Overview geologic map of Khiagdinsk ore field (according to the data presented by JSC "Rusburmash"): 1 – Neogene deposits; 2 - 3 basement rocks: sedimentary (a) and metamorphic (b) (2), granitoids (3); 4 – uranium-ore deposits; 5 – discontinuous faults of different types; 6 – the contour of Khiagdinsk ore field.

Geologically, within the zone, a large Caenozoic paleoriver system of Bol'shoy Amalat with major N-E flow was exposed under Miocene basalt mantle of 4000 sq. km in area. Paleovalleys are predominantly intersected by granitoid crystalline basement consisting of grey sedimentary rocks. Three units were distinguished in Neogen-Quaternary formations (bottom-up): terrigenous arkosite (80 m), igneous-sedimentary (120 m) and igneous (250 m); two lower units are comprised of a paleovalley system, upper – a superposed sheath (mantle) [3].

The geological structure of Khiagdinsk ore field is conditioned by the formation of two structural levels consisting of heterogeneous basement, predominantly granitic, and mantle of Cainozoic igneous- terrigenous formation.

Paleovalley basement and its margins consist of 90% highly-radioactive granitoids of Vitim-Kansk complex (25…40 mcR/h). In Pre-Neogene period all basement rocks were exposed to intensive chemical weathering resulting in the formation of overlying clay coarse-gravel weathering crust, the thickness of which was from 1 meter to ten meters. Transported clastic material forms Neogene productive sedimentary sequences in Dzhilinda suite.

Localized mineralization conditions within Khiagdinsk ore fields were considered by many researchers [4, 5, 6, 7, 8]. The question - what is the source of ore matter - remains is still open, and this defines the relevance and practical application of the study.

The purpose of the given paper is to study the composition of basement granitoids and their derivative products and determine their geochemical differentiation and potential ore source in paleovalley deposits.

2. Methods and material

The study is based on the materials of specialized mineralogical-geochemical survey of basement rocks and derivative products in Namaru-Koretkonde and Dybryn fields.

Rock composition was studied by traditional methods of optical diagnostics on transmitted -light and reflected -light microscopes in thin and polished sections by X-ray difractometer D2 Phaser (Bruker AXS GmbH, Tomsk, analyst – D.G. Usol'tsev).

Scanning electron microscope (SEM) Hitachi S-3400N with energy-dispersive spectrometer Bruker XFlash was used to determine the composition from Li to U with an element content more than 0.1 wt.

% in accessory microinclusions and ore mineralization (Training and Research Laboratory of Optical and Electron Microscopy, Uranium Geology International Center, Tomsk Polytechnic University).

To determine the chemical composition highly sensitive method of inductively coupled plasma mass spectrometry (ICP MS) was used to examine 60 elements in accredited laboratory of LLC Chemical-Analytical Center “Plasma”, Tomsk (supervisor – N.V. Fedyunina).

3. Results and discussion

Based on optical diagnostics and X-ray difractometry, the mineral composition of basement granitoids and weathering crust were investigated (not transported, slightly transported, transported).

Basement granitoids are characterized by mature mineral composition and structural features. Porphyric leucocratic (light-colored) biotite granites of subalkaline group are predominate. The major rock-forming minerals: quartz 20…35%, plagioclase 15…25%, K-feldspar 25…35%, biotite 1…5%, muscovite 1…7%. Accessory minerals (1…3%) includes apatite, zircon, sphene, magnetite, monazite, xenotime.

Weathering crust includes unlithified or weakly lithified sediments. Mineralogically and granulometrically, the following petrographic types of deposits are distinguished: sandy and sandy medium gravel and differ in large rock fragments.

They are light-gray rocks with gray, yellowish or brownish sections due to organic remain impurities and pyroclastics. Core samples revealed sand, granitic subsoil or gravel of weakly lithified irregular coarse rocks.

The microscopic study revealed their similar mineral composition. Based on this fact several types of sands can be distinguished: 1) quartz-feldspar sand without organic impurities and pyroclastics which could be a product of slightly transported redeposited weathering crust along subalkaline leucogranites; 2) quartz-feldspar sand with insignificant organic impurities and pyroclastics (up to 1…2%) which could be transported weathering crust along subalkaline leucogranites; 3) quartz-feldspar sand with organic impurities and pyroclastics (up to 7…10%) which could be a displacement product of transported weathering crust along subalkaline leucogranites and pyroclastic ash flows prior to the formation of the basalt plateau.

The electron-microscopic analysis of granitoid and weathering crust thin sections has revealed rare-earth minerals including rare-earth phosphates, presumably monazite (Ce, La, Nd, Th) [PO_4] (fig. 2) and xenotime (YPO_4) with low impurities of Ga, Dy, Er, Yb. These minerals are rather prevalent and include crystalline fines (2…4 mkm). Uranium (1 %) may be isomorphic impurities.

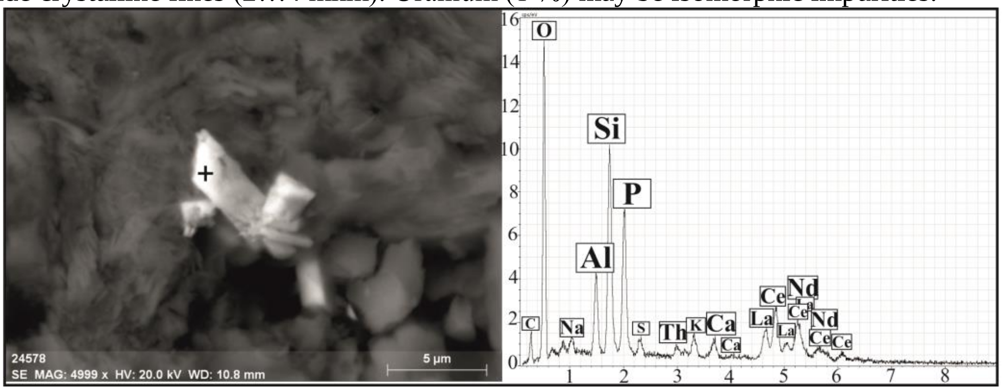

Figure 2. Koretkonde uranium deposit. C-5648, interval: 266.7…267.2 m. Monazite and its energy-dispersive spectrum

Electron-microscopic analysis showed the presence of aggregates and some zircon crystals of up to 10…40 mkm in diameter. There are few uranium-bearing (U about 8.5%) variations.

We have found intrinsic uranium minerals. Granitoid basement involves calcium phosphate (U 24%) (fig. 3) and titanate uranium (U 45%) (fig. 4). Examination of thin sections showed that calcium phosphate occurs as veinlets of up to 15 mkm or small grains in the quartz intergranular space. These veins are most likely to have developed in the postmagmatic stage of granitoid transformation.

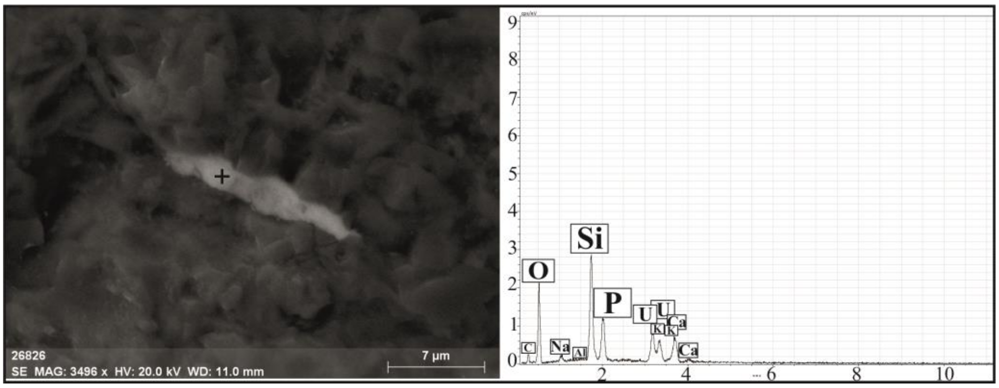

Figure 3. Koretkonde uranium deposit. C-5648, interval: 266.7…267.2 m. Calcium phosphate of uranium and its energy-dispersive spectrum

The energy-dispersive spectrum (fig. 3) revealed silicon which is governed by the siliceous crystal matrix (SiO), similar to uranium titanate.

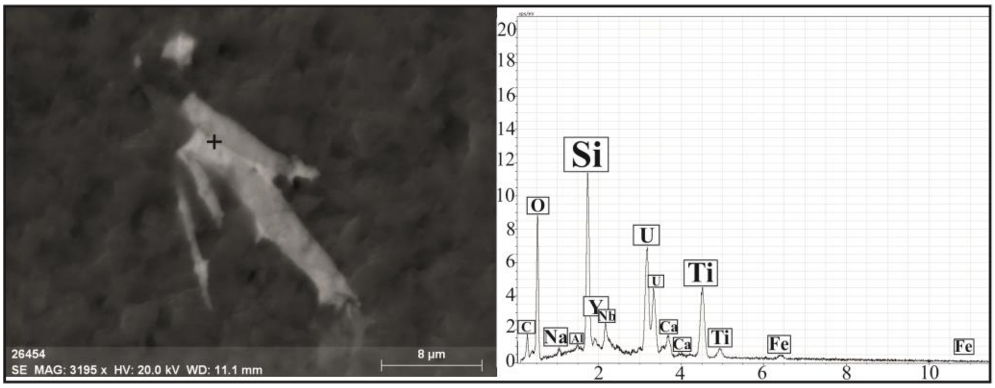

Figure 4. Namarus uranium deposit. C-5459, interval: 327.5…327.8 m. Uranium titanate (brannerite) and its energy-dispersive spectrum

In case of weathering crust natural uranium mineralization was found as calcium-uranium-phosphorous composition (U 32 %). These compounds are mostly finely-dispersed amorphous concentration within intergranular space of clay sands or granite fragments.

Another remarkable feature is the occurrence of iron sulfides (pyrite?) in granitoids and weathering crust. In granitoid basement there are iron sulfides as small crystal impregnations and aggregates. However, investigated weathering crust revealed concentrations of framboid pyrite everywhere which could be the result of the decomposition of organic matter due to bacterial sulfate reduction [9, 10].

In addition, we found significant impregnations of zinc, barium, silver, lead sulfides, as well as iron, titanium, copper, tungsten, silver, tin oxides and gold with impurities of silver, iron, copper, titanium. Intermetallic compounds of Sn, Cu, Zn, Fe, SiO, as well as native metals of W and Ni are revealed.

Analysis of uranium and thorium variations (fig. 5) based on ICP-MS data shows that granitoid basement and weathering crust are characterized by high radioactive thorium-uranium and natural uranium.

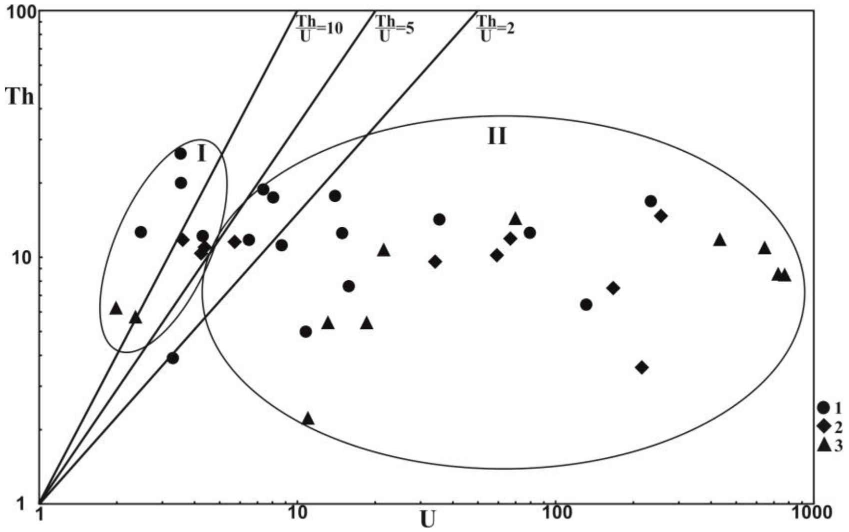

Figure 5. Diagram of content variations in uranium and thorium (according to L.V. Komlev; ed. by A.A. Smyslov): I – highly radioactive granites; II – highly radioactive substantially uranium-bearing granites. 1 – basement granitoids; 2 – slightly transported weathering crust; 3 –transported weathering crust.

4. Conclusion

Based on conducted analysis the following conclusions:
- basement granitoids are leucocratic (light-colored) biotite granite of subalkaline group;
- major accessory minerals of prevailing granitoids are apatite, zircon, sphene, magnetite, monazite, xenotime, single grains of calcium uranium phosphate and brannerite;
- increased concentrations of uranium and thorium indicate uranium – based granitoid basement;
- in the process of hypergene transformations weathering crust develops on granitoids composed of the following prevailing minerals: quartz and feldspar by 1:2, K-feldspar, granite fragments, pyroclastics, organic remains that demonstrate the arid conditions of its development;
- accessory and ore mineral composition in weathering crust include sphene, zircon, monazite, ningyoite;
- as a result of the areal uplifting during denudation a significant part of mantle was washed out and redeposited in paleovalleys;
- due to outwash and roundness of matter the following sediments can be distinguished: slightly transported and transported weathering crust;
- mineral composition of rock-forming components, ore minerals (sphene, zircon, monazite, ningyoite), uranium-thorium relation (from 0.01 to 3) of the weathering crust show that sediment composition of paleovalley and granitoids inherited from the sources of those sediments.

Based on the research presented above it can be concluded that granitoid basement of Vitim site could be a source of uranium-forming material of paleovalley type.

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