Material Composition of the Mesozoic Alkaline Rocks of the Yukhta Massif (Southern Yakutia, Central-Aldan Ore Region)

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Abstract. The paper considers the petrographic composition of the Mesozoic alkaline igneous rocks of the Yukhta massif. It is part of the Central Aldan ore region and is spatially located in the central part of the Nymnyr block. The massif is a large multiphase structure, of the most productive stage of the territory's development – the Mesozoic tectonic-magmatic activation of the Aldan-Stanovoy shield. Determination of the qualitative quantitative-mineralogical characteristics of the 2 and 3 phases of intrusion (emplacement) most promising for gold-radioactive mineralization with the help of crystal-optical methods was the main goal of this work. As a result of petrographic studies of Mesozoic alkaline igneous rocks, it is defined that, the Yukhta massif is a multiphase magmatic structure, with decrease of the content of dark-colored minerals in rocks from the early to later phases of intrusion. In general, the rocks of the massif bear significant traces of secondary changes, which are related to the gradual formation of the massif. According to the features of the composition of the massif rocks, it was found that the latter could be formed from residual differentiates during the fractional crystallization of rock-forming minerals with the involvement of plagioclases. The Yukhta massif is associated with the large Samolazovskoye gold deposit, which formation is related to an intense contact-metasomatic impact on carbonate rocks. Hydrothermal-metasomatic transformations of the latter are the products of multi-stage silica-alkaline metasomatosis associated with the second and especially with the third phases of the massif intrusion, and with further weathering processes, involving karst formation, disintegration of gold-ore metasomatites and the formation of a thick oxidation zone. From whence it is concluded that uranium being a chemically active element does not accumulate in a hypergenic form within the Yukhta massif. Where the weathering crust is intensively developed, a gold-ore type of mineralization is observed. On the other hand, the rocks of the massif itself, in particular syenites of the 2 and 3 phases of intrusion, may be promising for the uranium-thorium-rare earth (U-Tn-REE) type of mineralization. In general, these studies in this direction will provide insight into a number of issues related to the study of the evolution and metallogeny of the Mesozoic tectonic-magmatic activation of the Aldan-Stanovoy Shield

1. Introduction
The Central-Aldan ore region is located in the central part of the Aldan-Stanovoy shield and spatially coincides with the superterrain of the same name. In the west, along the Amga zone of tectonic melange, it borders with the West-Aldan terrain, and in the east along the Tyrkanda zone of tectonic mélangé - with the East-Aldan superterrain. In its geological structure, the Nymnyr and Sutam terrains,
separated by the Seim thrust, are recognized in its composition (Figure 1 A). Among the rocks composing the terrains, orthogneisses of granitoid composition are widespread, and primary sedimentary rocks are also occur in various quantities [1].

**Figure 1.** A – Schematic geological map of the Central Aldan superterrain [1]. B – Diagram of ore regions of the Chara-Aldan metallogenic zone of the Aldan-Stanovoy shield [2]:

1A: Terrains: ANM – Nimnyr, AST-Sutam; SM – Seimsky. 1 – Siberian platform cover; 2 – Amphibole, biotite-amphibole, diopside-amphibole, dipyroxene-amphibole plagiogneisses, rarely shales with interlayers and lenses of diopside, phlogopite-diopside rocks and calciphyres (Fedorov strata); 3 – Quartzites and high-alumina gneisses, with lenses of calciphyres, clay and diopside quartizes (Kurumkan strata), granite-gneisses; 4 – Garnet-biotite gneisses and plagiogneisses, hypersthene-biotite dipyroxene and diopside-amphibole plagiogneisses (Seimskaya strata); 5 – Granite-gneiss, charnockite-gneisses, enderbite-gneisses with lenses of dipyroxene crystalline schists; 6 – Tectonic mélange zones; 7 - rivers; 8 - Medvedev massif.

1B: 1 – ore-magmatic (gold-bearing) regions of the Aldan shield (1 – Murun-Soktokut, 2 – Usinsky, 3 – Upper-Anga, 4 – Centyral-Aldan, 5 – Nimnyr-Evotin, 6 – Tyrkanda, 7 – Lomamsky, 8 – Guvilgrinsky, 9 – Altan-Chaidakh; 2 – areas with supposed "blind" Mesozoic magmatism and mineralization (10 – Yarogin, 11 – Tolbachan); 3 – gold-bearing regions of the North-Stanovoy marginal suture (12 – Kabaktan, 13 – Sutamsky); 4 – Mesozoic upwarpsings; 5 – inter-arch zone of the Mesozoic depressions; 6 – areas of the Jurassic terrigenous deposits of the South-Yakutian basin; 7 – zone of step-flexural dislocations, bounding the Aldan shield from the platform; 8 – monoclinal structure of the platform (northern slope of the Aldan anteclise); 9 – rigid massifs, blocks (I – Chara-Kalar, II – Aldan, III – Timptonsky IV – Gonamo-Idyumsky, V – Khaikansky VI – Melemkinsky, VII – Sutamsky, VIII – Tokinsky); 10 – magma-controlling faults: ancient inter-block sutures, activated in the Mesozoic; 11 – magma-controlling faults, conjugated with the arcs; magmatic belts: ST – Stanovoy, CA – Central-Aldan, NA – North-Aldan; 12 – supposed boundaries between geological structures; 13 – Medvedev massif; 14 -rivers.
The Central Aldan ore region is the largest (figure 1 B), well-studied and economically developed gold ore region of the Aldan-Stanovoy Shield, which records large and unique gold deposits, such as Lebedinskoye, Gora Rudnaya (Morozkinskoye), Ryabinovoye, Lunnoye, Samolazovskoye, Garbuzovskoye, Dzhekondinskoye, Goltoo, Lopukhovskoye, Mramornyoye, Samodumovskoye, Tommotskoye, Zverevskoye, and Vysokoye, the gold deposits of the Kuranakh group, as well as the gold-bearing uranium and molybdenum-uranium deposits of the Elkon ore cluster, which together determine the current state of the mineral resource base of gold in the Central-Aldan region. The gold-ore potential of the central part of the Aldan Shield, according to most researchers [1,2,3, etc.], is largely due to the occurrence of the Mesozoic alkaline intrusive magmatism on its territory. This magmatism is related to the gold deposits of the Kuranakh, Lebedinsky and Ryabinovoye geological-commercial types.

Occurrences of alkaline and moderately alkaline intrusive magmatism within the Central-Aldan ore region form a large magmatogenic "focus", represented as insignificant in size intrusive massifs (Ryabinovoy, Gora Rudnaya, Yakutskoye, Dzhekondinsky, Yukhta, Purikansky, Yuzhny, Yllyamakshy, etc.), and in the form of dike belts and individual small bodies of lamproites, vogesites, minettes, kersantites, bostonites, syenite-porphyry, intruding rocks of the Precambrian basement and strata of terrigenous-carbonate rocks of the Vendian, Lower Cambrian and Jurassic [4].

Despite a long period of study of the Mesozoic alkaline magmatism of the Aldan-Stanovoy shield, many issues of evolution related to the Mesozoic activation of the territory and especially the metallogeny of igneous rocks remain debatable. In this regard, the study of individual massifs is relevant, which allows us to get an objective picture of the solution of these problems in general. The Yukhta massif is one of these formations. The obtained data will help to clarify the material composition of the phases 2 and 3 of the intrusion of the massif rocks, in our opinion - most informative and promising for gold-uranium mineralization, as one of the components of the alkaline rocks of the Mesozoic tectonomagmatic activation of the Aldan-Stanovoy shield.

2. Results of petrographic studies of igneous formations of the Yukhta massif
To determine the quantitative composition of the Mesozoic igneous rocks of the objects under consideration, 40 petrographic sections of the least modified differences were studied using MIN-8 polarization microscope, photos of the thin sections were taken on an Olympus BX 50 electron polarizing microscope, with a magnification of 25, 40, 100 Zeiss Axio Cam ICc 3 camera.

The Yukhta massif is localized in the central part of the Nymnyr block and is a large Late Jurassic-Early Cretaceous multiphase massif (146-157 Ma). [5]. The stocks, laccoliths, sheet bodies, and dikes of intrusive rocks of the massif intrude the formations of the Precambrian crystalline basement, the Vendian-Lower Cambrian carbonate rocks, and the Lower Jurassic terrigenous deposits of the sedimentary cover (figure 2). Numerous apophyses of alkali-feldspar syenites and syenite-porphyry are developed along the periphery of the massif, at the contact with carbonate rocks. In the north-west of the massif, massive large-crystalline varieties predominate, and in the rest of the area, porphyritic granosyenites with a fine-to medium-grained groundmass and tabular larger K-feldspar particles are developed. [5].
Figure 2. Geological map of the upper reaches of the Bolshaya Yukhta river basin, scale 1:50 000 (based on the materials of the GUGGP "Aldangeologiya"). 1-2 – Quaternary sediments: 1 – modern part, 2 – upper part; 3 – dikes, volcanic pipes, syenite-porphyry sills; 4-6 – Lebedinsky complex: 4 – third phase (stocks, laccoliths of granosyenites of porphyric and coarse-grained granosyenites and nordmarkites), 5 – second phase (stocks, laccoliths of quartz leucosyenites of medium-grained, porphyric), 6 – first stage (sills, stocks of alkaline earth syenites; 7 – dikes of lamproites, bostonites; 8 – Yukhta formation (sandstones); 9 – Ungelin formation (dolomites); 10 – Tumuldur formation (dolomites); 11 –dolomites; 12 – Ustydorn formation (dolomites); 13 – metasomatites and hydrothermalites of areal extent with partial replacement of the primary rock (1) and massive bodies with complete replacement of the primary rock (2); 14 – alkaline magmatites: granosyenites and nordmarkites (1), granosyenites (2), porphyric granosyenites (3), quartz leucosyenites medium-grained (4), quartz leucosyenites porphyric (5); 15 – carbonate rocks: marbles (1), marmorized undivided dolomites (2), skarns (3); 16 – faults: reliable (1), supposed (2), overlain by loose formations (3), main (4), secondary (5); 17 – geological boundaries: reliable stratigraphic and magmatic divisions of different ages (1), facial (2); 18 – gold deposits: Samolazovskoe (1), Garbuzovskoe (2)
Potassium feldspar is characterized by the presence of two generations. The first generation is represented by well-formed porphyry crystals of orthoclase with irregular outlines, which is characterized by a pertite structure. The first-generation Ksp phenocrysts are usually replaced by brown pelite (figure 3 c). The second generation of Ksp is represented by small grains of orthoclase of the groundmass, irregular in shape, partially or completely changed by secondary processes (figure 3 d). Plagioclase is represented by idiomorphic porphyry, prismatic individuals with irregular outlines (erosion) and melting rims. Late-generation plagioclase is replaced by sericite, less often by calcite and epidote. Quartz, occurs in the form of rounded porphyric inclusions and small shapeless segregations. Monoclinic pyroxene forms elongated, prismatic grains with irregular outlines, unevenly distributed over the rock (figure 3 e), intensely green in color with barely noticeable pleochroism.
Amphibole occurs in the form of rare prisms, as well as shapeless crystals, often replacing pyroxene (figure 3 f). Amphibole is characterized by phantom crystals of an aggregate of chlorite, calcite, and magnetite.

Figure 4. Granosienites of the third phase. a,b – Thin section. IS-16-6. General view. Magnification 25, nicols X; c – Thin section. IS-16-6. Perthite structure of potassium feldspar. Magnification 25, nicols X, d – Thin section IS-16-6. Underdeveloped plagioclase crystals. Magnification 25, nicols X; e – Thin section IS-16-7. Zonal plagioclase. Magnification 25, nicols X, f – Thin section. IS-16-7. Altered pyroxene. Magnification 40, nicols -.

The third phase of the complex is the most widespread in the territory. The rocks of the phase are composed of granosyenites, according to the identified morphological features of the body, they are stocks and laccolites of complex shape [5]. Granosyenites of the third phase are light gray, pinkish-gray, leucocratic rocks containing no more than 3% of dark-colored minerals. Hypidiomorphic structure predominates in them (figure 4 a ,b).

The rocks of the phase are characterized by a high content of plagioclase (up to 55%), low – Ksp (up to 35%), as well as quartz (up to 4%), dark-colored (up to 3%) and ore minerals (up to 3%). Two-
generation potassium feldspar. The first generation consists of rectangular, irregular porphyry orthoclase crystals with a characteristic perthite structure, partially replaced by products of secondary changes (figure 4 c). The second generation consists of small isometric orthoclase crystals that fill the space between the grains of Ksp and plagioclase of the first generation. Plagioclase is represented by two generations, the earlier of which is distinguished by porphyry crystals with underdeveloped faces (figure 4 d), irregularly accreting to each other, with typical polysynthetic twinning or distinct zoning (figure 4 e). Late generation – small irregular elongated crystals of the groundmass, with barely noticeable polysynthetic twinning, strongly altered by secondary processes. Quartz occurs both in the groundmass in the form of shapeless grains, and in the form of rounded phenocrysts. Pyroxene is represented by irregular elongated grains of aegirine-augite of intense green color with barely noticeable pleochroism (figure 4 f). Hornblende is found in the form of rare, small crystals with a sharp pleochroism, replaces pyroxene to complete phantom crystals. The ore mineral is unevenly distributed in the rock.

3. Conclusions

Thus, as a result of petrographic studies of the Mesozoic alkaline igneous rocks, it was determined that the Yukhta massif is a multiphase magmatic structure, with decrease of the content of dark-colored minerals in rocks from the early to later phases of intrusion. In general, the rocks of the massif bear significant traces of secondary changes, which are related to the gradual formation of the massif. According to the features of the composition of the massif rocks, it can be assumed that the latter could be formed from residual differentiates during the fractional crystallization of rock-forming minerals with the involvement of plagioclases.

The Yukhta massif is associated with the large Samolazovskoye gold deposit, which formation is associated with an intense contact-metasomatic effect on carbonate rocks. Hydrothermal-metasomatic transformations are the products of multi-stage metasomatosis, related to the second and especially the third phases of the massif intrusion, and to further weathering processes, involving kars formation, disintegration of gold-ore metasomatites and the formation of a thick oxidation zone [5]. The main part of the gold of metasomatites, as a result of their weathering, was probably released and moved to the environment of the products of the weathering crust. Perhaps, therefore, within the Yukhta massif, commercial gold mineralization of the hypergenic type was discovered.

Due to the fact that uranium is an active (mobile) chemical element and does not accumulate in a hypergenic form, within the Yukhta massif, where the weathering crusts are intensively developed, the gold-ore type of mineralization is mainly observed. On the other hand, the rocks of the massif itself, in particular syenites of the 2 and 3 phases of intrusion, may be promising for the uranium-thorium-rare earth (U-Th-REE) type of mineralization.

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