Petrography of the Mesozoic Alkaline Rocks of the Taezhniy Massif (South Yakutia, Aldan-Stanovoy Shield, Leglier Ore Cluster)

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Abstract. The article is concerned with the petrographic compositions of the Mesozoic alkaline igneous rocks of the Taezhniy massif and its small bodies (dikes). The Taezhniy massif is located in the central part of the Nimny block (Aldan-Stanovoy shield). According to our field observations, it was first determined that the Taezhniy massif has a two-phase structure, its rocks of contain syenite-porphyry and leucocratic syenites. The rocks of the massif intrude the Archean granites, and are themselves intruded by late dikes of bostonites and vogesites. Based on petrographic studies, we also identified two phases of intrusion in the Taezhniy massif – syenite-porphyry and leucocratic syenites. The difference of them is as follows: in the syenite-porphyry rocks, plagioclase predominates over K-feldspar, and the content of dark-colored minerals reaches 10%. The rocks of the second phase are characterized by the predominance of K-feldspar over plagioclase, with the content of dark-colored minerals up to 5%. The order of intrusion of the massif formations is determined by the presence of xenoliths of syenite-porphyry rocks in leucocratic syenites. The rocks of the bostonite dike cutting the massif are characterized by the absence of amphibole and an increased content of pyroxene. This is most likely due to the fact that, the rock contains xenoliths of the host rocks of biotite-pyroxene composition. The dikes also contain xenoliths of the second phase rocks, which indicates a later age of this dike. The bostonite dike located in the immediate vicinity of the massif is almost identical to the dike found in the massif, except an amphibole in the composition of the rocks. The only dike of vogesites that intersects the body of the massif is characterized by the presence of two varieties of amphibole: common hornblende and a sufficient amount of barkevikite, which phenocrysts stand out clearly against the background of the total microcrystalline mass. Also, in the course of crystal-optical studies, it was noted that in the structure of the massif there is an increase in the leucocratic magmatism from the early phase to the late, but with a decrease in this indicator, taking into account the introduction of vogesite dikes at the late stages of magmatism development. Based on this, the conclusion is made about the antidromic development of the rocks of the Taezhniy massif. When comparing the evolution of magmatism of the Taezhniy massif with the Ryabinoviy massif, a possible gold-ore specialization of the studied object is suggested.

1. Introduction
The problems of the genesis and identification of metallogenic specialization of ore areas related to the Mesozoic magmatism of the Aldan-Stanovoy shield are always relevant and debatable. The solution of the latter leads to various conclusions and decisions of many specialists [1,2,3 et al.]. One of the key
points in solving these problems is a comprehensive study of individual objects, in particular the study of the petrographic composition in relation to the conditions of formation and their metallogenic specialization. From this point of view, we chose the Taezhniy massif as the object of our study (figure 2), which was formed during the Mesozoic tectonomagmatic activation of the Aldan-Stanovoi Shield.

The Taezhniy massif is located in the central part of the Nimnyr block (figure 1), within the Evotinskiy gold-ore district. At the current level of the erosion section, the massif has the shape of an irregular ellipsoid, which long axis is oriented in the north-east direction (figure 2). According to our field observations, it was first determined that the Taezhniy massif has a two-phase structure, which rocks record syenite-porphry and leucocratic syenites. The rocks of the massif intrude the Archean granites, and are themselves intruded by late dikes of bostonites and vogesites.

2. Petrographic studies of rocks
In order to determine the quantitative composition of the Mesozoic magmatic rocks of the studied objects, 40 petrographic thin sections of the least changed differences were studied using the MIN-8 polarizing microscope, photos of the thin sections were taken with an Olympus BX 50 electron polarizing microscope with Zeiss Axio Cam ICc 3 camera, at an enlargement of 25, 40, 100.

The least common rocks of the Taezhniy massif are syenite porphyry, which form a small outcrop in the north-eastern part (figure 2). The structure of the rocks is porphyry. The texture is massive. The groundmass is microgranular, difficult to diagnose. Considering the features of the mineral composition, there is a predominance of plagioclase 60% over K-feldspar 20%, amphibole 8% over pyroxene 2%, quartz content 6%, apatite and zircon 2%, ore mineral 2%.

Figure 1. Tectonic scheme of the Aldan shield [4]. 1 – granite-greenstone terranes (WA – West Aldan, BT-Batomsky terrane); 2 – granulite-orthogneisic terranes (ANM – Nimnyrsky, CG-Chogarsky); 3 – granulite-paragneiss terranes (AST – Sutamsky, EUC-Uchursky); 4 – Tonalite-trondhjemite-gneiss terranes (TN-Tyndinsky); 5 – Zones of tectonic melange (am – Amginskaya, kl – Kalarskaya, tr-Tyrkandinskaya); 6 –Early Proterozoic granites; 7 – Siberian platform; 8 – faults (dj – Dzheltulaksky, ts-Taksakandinsky); 9 – study area.
Figure 2. A fragment of a schematic geological map [5] of the Leglier ore cluster, with additions by the authors. 1 – the rocks of the cover, 2 – gabbro poorly defined, 3 – olivine-pyroxene hornblendites, 4 – the Late Archean granites and granite-gneisses, poorly defined; Mesozoic igneous formations: 5 – syenite and monzonite massifs, dikes of: 6 – syenites, 7 – bostonites, 8 – vogesites, 9 – faults, 10 – rivers.

The porphyry structure of the rocks is caused by the presence of K-feldspar, plagioclase, and amphibole phenocrysts up to 5 mm. K-feldspar phenocrysts in syenite-porphyry are represented by irregularly shaped grains with low interference colors ranging from gray to dark gray tones, often in the form of simple twins, which edge parts are corroded. Grain boundaries have the character of sutures and perlitic structure. Idiomorphic prismatic plagioclase crystals of early generation (figure 3 a) are characterized by polysynthetic twins and zonal individuals that are intensively sericitized (figure 3 c) (central parts), and fused in the marginal parts. Late generation of plagioclase – small crystals of the microgranular groundmass. Amphibole phenocrysts are represented by early-generation hornblende and are recognized as prismatic and irregular crystal shapes, as well as rare mono-aggregates. Pleochroism colors from yellowish-greenish to greenish-brown shades. Interference color from light brown to dark green, extinction angle up to 40o. It is worth noting the presence of hornblende in the form of simple twins, as well as zonal individuals (figure 3 b, d). The late generation of amphibole, along with the late plagioclase, is found in the form of inclusions in the first generation K-feldspar. Pyroxene is represented by individuals of prismatic habitus (figure 3 e), is strongly altered, with the development of hornblende along it, and is rarely zoned. It has the highest colors of interference coloring. Quartz, along with the minerals of the groundmass, fills the space between the porphyry phenocrysts of K-feldspar and plagioclase, and is also present in the form of crack fillings in the rock (figure 3 f). The main mass of the rock is brownish in hue, represented by significantly altered hard-to-diagnose microcrystals of K-feldspar and plagioclase (abundant pelitization and sericitization). Ore mineral, has a uniform distribution and equal size in the form of independent grains or completely replaces dark-colored minerals.
Figure 3. Syenite-porphyry. a – porphyry crystals of K-feldspar and plagioclase, magnification 40, nicols +; b – first generation plagioclase, magnification 20, nicols +; c – sericite in plagioclase, magnification 100, nicols +; d – zonal amphibole, magnification 40, nicols +; e – pyroxene accumulations, magnification 40, nicols +; f – quartz veinlets, magnification 20, nicols +. Mineral abbreviations [6]: Amp – amphibole; Ap – apatite; Bt – biotite; Cpx – pyroxene; Kfs – K-feldspar; Ksen – xenolith; Pl – plagioclase; Qz – quartz; Ser - sericite.

Leucocratic syenites are characterized by the greatest distribution in the structure of the Taezhniy massif (figure 2). Rocks with a hypidiomorphic-granular structure and a massive texture. Regarding the features of the petrographic composition of the least changed differences, it is worth noting the predominance of K-feldspar 60% over plagioclase 30%, amphibole 3% over pyroxene 1%, the content of biotite 1% and quartz up to 5%. The rocks contain numerous xenoliths of syenite porphyry of the previous phase, as well as the host rocks of the basement (figure 4 b). In general, the rocks of the phase are significantly quartz-flooded. In the southwestern part of the massif, quartz druses are found in the fragments of metasomatites (Archean granites).

We have identified two generations of K-feldspar in the petrographic composition of leucocratic syenites. The earliest of which - large crystals of irregular and rectangular shapes, characterized by low interference colors from gray to dark gray tones. The first generation K-feldspar crystals are characterized by a pertite structure and the absence of sutures. The K-feldspar phenocrysts contain fine plagioclase and amphibole in the marginal parts (figure 4 c), and also partially pelitized, resulting in acquiring a brownish color in the places of change. The second generation – small grains of the prismatic nature of the groundmass, sometimes in the form of simple twins. Plagioclase is also of two generations. The first is prismatic, tabular phenocrysts with polysynthetic twinning (figure 4 d), as well as a zonal structure. Plagioclase of early generation is serecitized both in the central and peripheral parts. The second generation is in the form of small altered crystals of the groundmass and prismatic crystals of polysynthetic twins. Amphibole in the form of hornblende, prismatic, irregular crystals of greenish or greenish-brown color (figure 4 e, f). Rare pyroxene grains are observed in the form of short-prismatic individuals, they slightly pleochroate in light green tones, they are subject to secondary changes and are unevenly distributed in the rock as a whole. Biotite in the form of plates and laths with bird's-eye fading from light brown to almost black, developed along the hornblende. Quartz of postmagmatic origin fills the space in the gaps of the groundmass, as well as the space between the porphyry phenocrysts of K-feldspar and plagioclase.
Figure 4. Leucocratic syenites. а – general structure of the rock, magnification 40, nicols +; b – xenolith syenite-porphyry in rocks of the second phase, magnification 40, nicols +; c – inclusions of small amphibole and late-generation plagioclase in K-feldspar, magnification 40, nicols +; е – amphibole phenocryst, magnification 20, nicols +; f – biotite growth in amphibole, magnification 40, nicols +. Abbreviations of minerals are shown in the figure 3.

Rare dikes of bostonites are found both in the Taezhniy massif and in the immediate vicinity of it. The rocks are characterized by a bostonite structure and a trachytoid texture. Rock composition: potassium feldspar (K-FS) – 60%, plagioclase-15%, pyroxene-15%, amphibole-5%, biotite-5%. Small xenoliths of host rocks of the basement and leucocratic syenites of the Taezhniy massif are found in the dike (figure 5 а, b), which indicates a later age of the rocks of this dike in relation to the massif.

The bostonite structure of the dike rocks is due to the sinuous outlines of the laths of K-feldspar and plagioclase, both oriented and randomly located in the rock (figure 5 а). K-feldspar is present in the form of rectangular elongated laths (figure 5 а), as well as in the form of rare phenocrysts, the boundaries between them are recognized as sutures (figure 5 с). K-feldspar crystals are characterized by simple twins, partially or completely pelitized; extremely rarely have a pertite structure (irregularly shaped inclusions of albite in the orthoclase elongated in one direction). Altered by secondary processes (sericitation of core and peripheral parts), plagioclase is represented by rectangular, prismatic grains with irregular outlines, with simple and polysynthetic twinning in the form of laths and rare phenocrysts (figure 5 d). Pyroxene, represented by prismatic, irregular grains with irregular outlines, is also altered by secondary processes (figure 5 а) and has interference colors of the highest order (figure 5 е). Hornblende is represented as phenocrysts of regular elongated shape (figure 5 b), and irregular flakes; has good cleavage. The mineral is yellowish-brown, greenish with blue-green and dark green color of pleochroism. Rare simple amphibole twins (barkevikite?), as well as crystals of zonal structure are also observed in the rock. Biotite is observed in the form of plates and laths, with the extinction of the "bird's eye" type. It is represented both in the form of independent grains and in the form of mono-aggregates (figure 5 с). The contact of the studied dike with the host metasomatites of the Taezhniy massif is smooth and clear (figure 5 f).
Figure 5. Bostonite dike. a – xenolith of host biotite-pyroxene rocks, magnification 40, nics +; b – xenolith of rocks of the second phase of the massif, magnification 40, nics +; d – K-feldspar phenocryst, magnification 20, nics +; d – plagioclase phenocryst, magnification 40, nics +; e – pyroxene phenocryst, magnification 40, nics +; f – contact with the massif metasomatites, magnification 20, nics +. Abbreviations of minerals are shown in the figure 3.

The vogesite dike (figure 6) is located in the southern part of the Taezhniy massif, it has a lamprophyric structure, a massive texture, and the following composition: plagioclase and K-feldspar – 50% (groundmass), hornblende – 35%, clinopyroxene – 5%. The groundmass of the rock is microcrystalline and difficult to diagnose even at large magnifications. In addition to the idiomorphic phenocrysts of ordinary hornblende, idiomorphic simple twins and zonal crystals of barkevikite are often observed (figure 6 a, b). Pyroxene is represented by rare transparent prismatic crystals with a light green hue and interference colors of the highest order. Contact with the host rocks is smooth, clear.

Figure 6. Vogesite dike. a – general structure, magnification 20, nics +; b-c – varieties of hornblende, magnification 40, nics +. Abbreviations of minerals are shown in the figure 3.

3. Results and discussions
Based on field work and petrographic studies, we have identified two phases of intrusion in the Taezhniy massif – syenite-porphry and leucocratic syenite. The first phase of the massif is represented by syenite-porphry with a content of dark-colored minerals up to 10%. In the rocks of phase 1, the predominance of plagioclase over K-feldspar is noted. The rocks are characterized by sutures and the pertite structure of the K-feldspar. The melting of the marginal parts of the plagioclase
is noticeable. The second phase, bearing xenoliths of syenite-porphyry, indirectly indicating a younger age, is represented by leucocratic syenites (the content of dark-colored minerals is up to 5%). The rocks of the second phase are characterized by the predominance of K-feldspar over plagioclase. It is characterized by the absence of sutures of the K-feldspar, the latter contains a small plagioclase and amphibole in the marginal parts.

The rocks of the bostonite dike in the massif are characterized by the absence of amphibole and an increased content of pyroxene. This is most likely due to the presence of xenoliths of the host rocks of biotite-pyroxene composition in the rock. The dikes also bear xenoliths of the second phase rocks, which indicates a later age of this dike. The bostonite dike located in the immediate vicinity of the massif except for the appearance of an amphibole in the composition of the rocks is almost identical to the dike found in the massif. The only vogesite dike found in the body of the massif is characterized by the presence of two varieties of amphibole: common hornblende and a sufficient amount of barkevikite, which phenocrysts stand out in relief against the total microcrystalline mass.

It is worth noting that in the adjacent territory within the Central Aldan ore region, the main part of the gold deposits is related to multiphase Mesozoic magmatism, the antidromic character of which, within the same Ryabinoviy massif (Aldan and Tobuk complexes), played a key role in the localization of the gold-copper-porphyry ore mineralization of the same-name deposit [7].

4. Conclusions
Thus, in the course of crystal-optical observations, it was revealed that the Taezhniy massif has a two-phase structure, where there is an increase content of salic minerals from the early phase to the late, but with a decrease in this index, taking into account the intrusion of vogesite dikes at the late stages of magmatism development. The dikes of bostonites and lamprophyres are younger in relation to the rocks of the massif due to the presence of xenoliths of the massif rocks in them. According to the similarity of the evolution of magmatism of the Taezhniy massif with the Ryabinoviy massif, there is reason to assume that gold mineralization may also be related to the studied massifs, but this requires further research.

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