Geological Features of Volcanic Rocks of the Lower Taiga Ore Area (Russia, Primorsky Krai)

V V Ivın¹, E I Medvedev¹
¹Far East Geological Institute, Russian Academy of sciences, Russia

E-mail: Cage21@mail.ru, ivin_vv@mail.ru

Abstract: This article is about features of geological structure and composition of volcanic and sedimentary rocks of the Low Taiga area (Russia, Primorsky region). This area is a part of the east Sihote-Alin volcanoplutonic belt, is located in the area of transit from the continent to the ocean. Studings of geological and chemical composition, structure and patterns of placement of the Low Taiga Area’s volcanic sedimentary rocks allow us to complete information about geological and geochemical features of Mesozoic-Cenozoic stage of the formation of the said structure. Unever igneous formations are distributed within this area, classified to Primorsky (turonian senonian), Samarga (maastrichtian), Bogopolsky (Paleocene) and Kizinsky (Miocene) volcanic complexes. Matching volcanic rocks complex’s chemical composition with published data testifies to significant similarity with petrotypes of ternei volcano structure. Besides it was found that the Low Taiga Area’s complexes contain high potassium varieties and vary in contents of rare and rare earth elements. Distribution of incoherent elements of primorsky complex’s volcanics are characterized by increased concentrations of tungsten, zinc, plumbum, thorium, lanthanum, cerium, by low content of niobium, strontium, zirconium and titanium. Samarga complex is characterized by low content of titanium and strontium, by low content of neodymium. Bogopolsky and Kizinsky complexes in the distribution of rare and trace elements have a similar trend appearance with petrotypes, but differ in the level of their concentration.

1. Introduction

The Nizhne-tayechny polymetalli core cluster is located in littoral zone of the East-Sikhot-Alin volcanoplutonic belt (ESAVPB) which represents a combination of Late Cretaceous volcanic complexes and related intrusive bodies lining upalongside the western shore of the Sea of Japan and the Strait of Tartary. As an independent structure the belt was first recognized by N.S. Shatsky in 1957 and has become an objective of study for many scholars. A.V. Mikhailov [1] was the first who summarized the diverse information on tectonics-magmatism relationship inherent within the ESAVPB. Most researchers (A.I. Khanchuk, Yu.A.Martynov, G.A. Valuy, V.K. Popov, V.G. Sakhno, etc. [2]) consider the belt a characteristic outcome of volcanismmoccurred on continentalmargins due to certain tectonic processes, most likely due to subduction (A.I. Khanchuk [3]). There is another opinion though that it is a result of transtensional tectonics (V.P. Utkin [5]). Nevertheless, all the scientists agree that Meso-Cenozoic magmatism on the East Asian continental margin was very complicated and that the change of the Pacific Plate’s motion vector has led to the transition of the then above-subduction regime to transform boundaries followed by an active volcanocity. Geochemistry of volcanic complexes from the Nizhne-tayechny ore cluster has been thoroughly studied at Analytical Center of Far East Geological Institute of the Far Eastern Branch of the Russian Academy of Sciences, Vladivostok, using up-to-date
instrumental methods. Basic elements content was determined by X-ray fluorescence method with the help of Bruker S4 Pioneer XRF spectrometer (analyst E.A. Nozdrachev), and the rare and trace elements were detected by ICP-MS method with Agilent 7500c instrument (analyst M.G. Blokhin).

2. Geological background
The Nizhne-taezhnaya ore cluster (NTOC) occupies an area of more than 500 square kilometers with in the littoral section of East-Sikhote-Alin volcanoplutonic belt (ESAVPB) and adjoins the well-studied Terney volcanic formation. A complicated geological structure of the NTOC is conditioned by the presence of large submeridional faults on the area. Stratified deposits of the cluster can be divided into lower terrigenous layer, strongly contorted into NE-striking folds, and upper volcanogenic one comprising pyroclastic deposits of the Primorsky (Turonian-Campanian), the Samarga (Maastrichtian), the Bogopolsky (Maastrichtian-Danian), and the Kizinsky (Micene) volcanogenic complexes [6].

More than 30 ore zones are uncovered within the area, with dominating rare-metal, polynometal, tin-polynometal-silver, polynometal-silver, silver and gold mineralization. The tin-polynometal-silver-containing ore zones (Belembinskaya, Bortovaya, Ruslovaya, etc.) are found in hornfelsed volcanic rocks along endocontact of the Malinovskaya intrusive body and represent a system of steeply-dipping quartz veins impregnated with polynometal-sulfide mineralization.

The silver-rich ore zones (Kumirnaua, Blizhnaya, Vodorazdelnaya, Zamanchivaya, Krainyaya, Neyasnaya, Perevalnaya, Sentyabrskaya, Syurpriz, etc.) have low sulfide content and spatially are isolated from the tin-polynometal-silver ore zones. Host rocks of the silver mineralization are quartz-sericite-hydromicametasomatites developed after volcanic rocks and representing veins composed of semitransparent comb quartz containing silver sulphosalts.

3. Composition and geochemical features of volcanic complexes
Volcanogenic rocks of the NTOC are results of the Upper Cretaceous, Paleocene and Miocene magmatism. The Cenomanian-Maastrichtian volcanic belong to the Primorsky and Samarga complexes, with the former composing a large part of the area being constituents of different volcano-tectonic formations. Petrographically, volcanic rocks of the Primorsky complex are divided into three lithologic units.

First (lower) unit (K2pr 1) is made up of psammitic and psephitic-psammitic lithic-crystal tuffs of rhylolite containing basement fragments and rare rhylolitic ignimbrites. Visible thickness of the unit is 250 m. Rocks of this unit are wide-spread in the east of the NTOC as well as in the Tayezhnaya River banks.

Second (middle) unit (K2pr2) consists of psephiticand psephitic-psammitic welded tuffs of rhylolite with rare intercalations of ignimbrites and vitric tuffs. A distinct feature of this unit is presence of secondary alteration minerals like quartz, hydromica and propylite. The thickness of the unit varies from 250 to 450 meters.

Third (upper) unit (K2pr3) is the thickest one, about 450 meters, composed predominantly of ignimbrites with minor presence of volcanic glass and welded tuffs of rhylolite.

Most of contacts of the volcanogenic formations of the Primorsky complex with over- and underlying beds represent various tectonic dislocations. The exception is an encatchment area of the Berezovyi Brook where rocks are conformably overlapped by the strata of the Samarga complex [7]. Along faults and close to extrusions and necks of the Samarga complex, the rocks of the Primorsky complex underwent sericitization and silicification to form quart-sericite and andalusite-quartz-sericitemetasomatites.

The extrusive formations outwardly and compositionally are so akin to the host volcanics that it becomes hardly to recognize them from each other. The largest of them (10-15 km²) are concentrated in the center of Nosyrevskaya caldera situated on the left bank of the Belembbe River, where together with granitic intrusions they form local intrusive dome structures. Smaller extrusions of the Samarka complex are abundant in the watershed of the Kamenisty Brook and on the right bank of the Petrovanova Brook.
Effusive rocks represent magnophile rhyolites which sometimes become granite-porphyry, and clastic silicic lava. The largest extrusive formation on the left bank of the Belemebe River is made up of ignispumites went through silicification and epidotization. Marginal parts of the extrusive formations sometimes reveal breccia characteristics; several formations demonstrate well-preserved agglomeratic texture.

4. Results and discussion
Chemical composition of igneous rocks of the Primorsky complex is high-K varieties with medium alumina and normal or high silica contents referring them to the calc-alkali series. Their position on TAS classification diagram falls into the field of rhyolites. By concentration of chemical elements normalized to the Upper Continental Crust (UCC) intermediate composition [8], they correspond to igneous rocks inherent in continental margins. Distribution of REEs in volcanogenic rocks of the NTOC yielded a gently rising curve with a minimum for Eu. If compared to clarites of chemical elements in the UCC, effusive rocks of the Primorsky complex has enhanced concentrations of tungsten, lead and zinc.

The Samarga complex comprises volcanogenic formation and associated extrusions of andesites, andesidacites and dacites. The formation is made up of rhyolite-dacitic, dacitic, rarely andesitic tuffs of various textures. There are also tuffites, tuff siltstones, and tuff sandstones. With such facies diversity, the formation is characterized by the presence of coarse tuffs and xenotuffs at the bottom of the section and andesitic lava sheets on the top. Total thickness of the deposits exceeds 500 meters.

The rocks of the formation underwent strong chemical alteration taking on quartz-sericite characteristics, up to formation of secondary quartzite and transformation of rocks minerals into clay and propylite. Areal alterations are dominated by eruptive apparatus, necks of dacite, and an array of contiguous faults.

Extrusive formations are abundant within the Nosyrevskaya and Shanduyskaya calderas. The size of necks and extrusive domes rarely exceeds 0.3 square kilometers. Compositionally there are homogenous as well as heterogenous bodies resulted from the repeated intrusion events. By the silica content and the time of effusion, the rocks are subdivided into two groups – the early silicic spherolite and fluidal-spherolite rhyolites, rhyodacites, breccia lavas and xenotuffs, and the late-mediasilicicandesites and andesidacites.

Judging by silica and potassium ratio, these rocks relate to a high-K series. Their REE distribution pattern is characterized by a slightly recognized Eu minimum, with curves steeply dipping from La to Eu and continued lowering from Gd to Lu.

The Paleogene magmatism produced volcanogenic rocks of the Bogopolsky complex taking part in the Talnikovskaya and Shanduyskaya calderas’ structure. Stratified accumulations of this complex are divided into three lithologic units [7]:

First (lower) unit is composed of rhyolitic tuffs and tuff conglomerates with tuff siltstone intercalations and rounded blocks of dacite and granite. The unit is situated along the border of the above-mentioned calderas and has a thickness of 250-250 m.

Second (middle) unit is made up predominantly of ignimbrites-vitrified to varying degrees and welded ignimbrite tuffs. The rocks are weekly altered in the main, albeit there are quartz-sericitetereplacement and rare carbonate formations. Around fissures the rocks underwent silicification, hydromicronization and sulfidization. The thickness of this unit has a range of 250-650 m.

Third (upper) unit composes inner part of the Shandunskaya caldera. Being bedded above the underlying formations through a tectonic contact it has a thickness of more than 500 meters. The unit consists of typical tufogenic sedimentary rocks and tuffs. At the bottom they alternate with rhyolitic, ignimbritic as well as ignimbrite-like rhyolitic tuffs, while in the middle part they are massive pelitic tuffs.

Volcanogenic formations of the Bogopolsky complex are also found within the Nosyrevskaya caldera as dacitic, trachidacitic and andesidacitic flows [10], sublatitudinalrhyolitic, granitic and rarely andesitic dykes up to 2 km long.

Rocks of the Bogopolsky complex is presented in (Na2O+K2O)/SiO2 classification diagram, falls into fields of andesite, dacite, trachidacite and rhyolite. The potassium and silica ratio refers them to
high-K series, and the REE distribution pattern is similar to those presented in [2], only differing in concentration level.

According to A.V. Grebennikov [9] \((\text{FeO}_{tot}/(\text{FeO}_{tot}+\text{MgO})/\text{SiO}_2\) diagram), hyaloignimbrites and welded tuffs of the Bogopolsky complex correspond to a ferriferous variety, however our data show that they are rather intermediate, partly ferriferous - partly magnesian varieties.

The Miocene volcanogenic formations attributed by V.N. Korolev [7] to the Kizinsky complex are found in the eastern part of the NTOC as dacitic domes cut by dykes of andesite. The formations are encompassed by volcaniclastic breccias of diorite, rhyolite and granite.

By chemical composition, rocks of the Bogopolsky complex are fall ontotrichidacite, dacite and rhyolite fields and belong to high-K series rocks. On the chondrite-normalized REE distribution patterns, they have weak drop in Eu content, and on UCC-normalized incoherent element concentration patterns they have distinct Ti minimum along with K maximum.

5. Conclusion
The research on geochemistry of volcanic complexes of the Nizhnetayezhny ore cluster represents an important compliment to the study of their lithologic characteristics [7]. Igneous formations within the area under study are different in age, such as: the Turonian-Senonian Primorsky complex, the Maastrichtian Samarga complex, the Paleocene Bogopolsky complex and the Miocene Kizinsky complex. The comparison of chemical compositions of rocks constituting these complexes with the published analogous data on the petrotypes rocks constituting the Terney volcanic structure has revealed their similarity [2]. The volcanic complexes of the NTOC are composed of high-potassium series of rocks, differing in concentrations of incoherent and rare-earth elements. For example, the Primorsky complex are characterized by high contents of W, Zn, Pb, Th, La, and Ce, and low contents of Nb, Sr, Zr, and Ti. The Samarga complex has also got low contents of Ti and Sr, but high content of Nd. The REE distribution patterns for the Bogopolsky and Kizinsky complexes are akin to those for the Terney rock types, however concentrations are different. The REE distribution curves are harmoniously dipping from La to a weak Eu minimum and then flattening out from Gd to Lu.

6. References
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