Geochemical Characteristics of Igneous Rocks of the Nizhnetaezhny Ore District (North Primorye)

E I Medvedev¹, V V Ivin¹

¹Far East Geological Institute, Far East Branch of the Russian Academy of Sciences

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

Abstract. The article discusses the features of the geological structure and composition of the magmatic rocks of the Nizhnetaezhny ore district (North Primorye). It includes the East Sikhote-Alin Volcano-plutonic belt (ESAVPB) and is located in the transition zone Continent Ocean. ESAVPB is the typomorphic link of the East Asian Occino-Continental Volcanogenic, reconstructed by A. I. Khanchuk as an oversumbays. Other links are known as the Okhotsko-Chukchi, Busan and Southeast Chinese belts. To determine the age of the magmatic arrays, the NTOD selected from the two most representative intrusive bodies of the node of the Malinovsky and Berezovsky masses, between them the main mass of ore mineralization is located. The determination of the ages of the K-Ar method is shown that quartz diorites were formed in Paleocene (64 ± 1 million years), and biotite porphyrene granites in Eocene (47 ± 2 million years). It was previously assumed that the Malinovsky massive is a typical representative of Primorsky, and Berezovsky and the Zavodskoy - Samarka or Bogopolskaya volcanic Plutonic Complex. Considering that some definitions show (62 ± 1 million years) and characterize porphyry dacites in the Exocontact attacked of the Berezovsky massive, and in the bottom of the incision of the bogopolskaya suites, the lumpy tuffs of rhyolitic and tuff-conglomerates contain retaled and half-rolled fragments of the myarol granites common in the Primorsky complex, we can conclude About accessories Malinovsky and Berezovsky massive to the Samarkinskiy complex. In favor of such a conclusion, the determination of the age of monzodiorite (64 ± 1 million years) and pyroxene diorites (57 ± 2 million years) of the Malinovsky massive, which are consistent with the refined rates of the age of the Samargna suite, are appropriate.

1. Introduction
The Nizhnetaezhny ore district (NTOD), where in 2006 Ivin et al [1] discovered tin-polymetallic-silver, polymetallic-silver and silver mineralization, is located in the central part of East-Sikhote-Alin volcano-plutonic belt (ESAVPB). Together with three other belts: Okhotsk-Chukchi, Busan, and Southeast China [2], they combine into East Asia continental-margin volcanic arc reconstructed by A.I. Khanchuk [3] as the one formed above the subduction zone. At a certain dirvesity, all the belts possess similar features, such as staged formation, large extent and thickness of volcanic accumulations of subsilicic, mediaisilic and silicic composition, geochemical characteristics and metallic specialization [4]. Geological and petrological study carried out by G.A. Valuy [3]) made her possible to arrange the intrusive formations of the ESAVPB into groups on the basis of quantity of magmatic phases, volume of the intruded magma, remoteness from the sea coast and others parameters. She recognized large multiphase massifs of uniformly granulated magnetite-series diorite-granodiorite-
granitic rocks (coastal type); relatively small two-phase massifs of uniformly granulated and/or porphyry granodiorite (adamellite)-granitic rocks (arminsky type); and weakly-to-moderately differentiated monophasic massifs of ilmenite-series monzodiorite (diorite)-granodioritic (sometimes granitic) rocks (dalnegorsk and krasnorechensk types).

2. Geological structure
Several magmatic centres were revealed on the square of the Nizhnetaezhny ore district. These are Malinovsky, Berezovsky, Zavodskoi massifs, and others. The largest of them is the Malinovsky massif. In the layout it is an oval body surrounded by a wide contact metamorphic halo. Geophysical data (Dmitrook, 1974) show that the massif is rather poorly eroded and not uniform in structure. It is made up predominantly of fine-, rarely coarse-grained biotite–hornblende quartz diorites and fine- and coarse-grained biotite-porphyry granites changing to granite-porphyry on the periphery. The quartz diorites form central and western parts of the intrusion. The contacts between the diorites and the leucocratic granites cutting the intrusion body are usually not distinct and look like a transition xenolith-containing zone up to 100 m wide.

3. Geochemical research

(Na2O+K2O) vs. SiO2 classification diagram for rocks of the Malinovsky massif shows that geochemically they are akin to diorites, granodiorites and granites (Fig. 1A). Comparison analysis of composition of rocks of the NTOD and the published data [3] has revealed general similarities. For example, according to alumina-silica ratio [5], the granites situate mainly within fields of moderately alumina rocks, and diorites – within fields of high, moderately, low silica and alkaline rocks (Fig. 1B).

![Figure 1 (A, B). A) Diagram (Na2O + K2O) - SiO2 classification and nomenclature of intrusive rocks NTOD. B) Typification of NTOD intrusive rocks by alumina index (alkalinity) and silicic acid content (Shkodzinsky et al., 1992). I-V- fields of rocks of different alumina content (alkalinity): I - hyper-alumina, II - high-alumina. S-type; III - moderate alumina, IV - low alumina. I - type; V - alkaline. incl. A - diorites, granodiorites, granites of the Samarga complex NTRU; B - granites of the Bogopol complex NTOD; D - diorites, granites of the Oprichninsk massif [3].](image-url)
diagram of J. Pearce, all intrusive rocks of the NTOD massifs plot in the field of island-arc settings (Fig. 3).

**Figure 2 (A, B).** A) Petrochemical typification of NTOD intrusive rocks [6]. I-V - polarity and groups of series (in brackets): I-calcareous (low-potassium tholeiitic); II - calc-alkaline (medium potassium and high potassium); III-subalkaline (high potassium); IV - alkaline basalt; V - alkaline (nephelinite-phonolite). Dashed lines - main trends: AB - alkaline-basalt, CA - lime-alkaline. Numbers in circles trends: 1 - island arc calc-alkaline, 2 - orogenic calc-alkaline. incl. A - diorites, granodiorites, granites of the Samarga complex NTOD; B - granites of the Bogopol complex NTOD; C - diorites, granites of the Oprichinsky massif (Valuy G.A., 2006). B) FDistribution of rare earth elements in intrusive rocks of NTOD normalized to chondrite (Boynton, 1984), incl. 1-4 complexes of NTOD: 1- granites, 2,3 - diorites of Samarginsky, 4 - Bogopolsky granites; 5-6 Oprichinsky massif: 5 - granites, 6 - diorites [3].

The Berezovsky and Zavodskoi intrusive massifs also have several phases of emplacement. One of them is represented by fine-grained miarolitic alaskite granites which acquire an aplite texture in endocontact zones. The other phase is composed of coarse-grained pyroxene-hornblende diorites (sometimes gabbro-diorites), which are changed in apical and endocontact zones for distinctly porphyry varieties turning into typical pyroxene-hornblende-biotite diorite porphyry.

**4. Results and discussion**

K-Ar dating of rocks of the Malinovsky and Berezovsky massifs, the two most representative intrusive bodies of the Nizhmetaezhny ore district between which buck of ore manifestations was found, has yielded the following ages for the quartz diorites and biotite porphyry granites: 64 ±1 Ma and 47±2 Ma, Paleocene and Eocene, respectively [8]. The Malinovsky massif was referred earlier to the Primorsky volcano-plutonic complex, and the Berezovsky and Zavodskoi massifs - to samarginsky or bogopolsky volcano-plutonic complexes. However, the age of 62±1 Ma determined for the porphyry dacites from exocontact zone of the Berezovsky massif, and the presence of so typical for the Primorsky complex miarolitic granites as rounded and semirounded debris in blocks of rhyolitic tuffs and tuffaceous conglomerates at the bottom of the Bogopolsky section, allow the conclusion about belonging of both Malinovsky and Berezovsky massifs to the same Samarginsky complex. This
conclusion is supported also by the ages of 64±1 Ma and 57±1 Ma determined for monzodiorites and pyroxene diorites from the Malinivsky massif. These data are in agreement with the improved ages for the bottom of the Samarginskaya formation published by Sakhno et al. (2007).

![Image of a graph showing geodynamic position of intrusive rocks of NTOD and Oprichninsky massif (Pearce et al., 1984; Lipman, 1988), in coordinates of Rb and Nb + Y contents. Col G - collisional granites; WPG - intra-slab granites; ORG - ocean ridge granites; VAG - granites of volcanic arcs. Incl. 1-2 complexes of NTOD: 1 - Samarga granites; 2 - Bogopolsky granites; 3 - granites of the Oprichninsky massif [3].]

5. Conclusion

Geochemical characteristics of granitic rocks of the Malinovsky massif thus testify that they presumably are results of melting of sedimentary rocks. Geochronological data from the Malinovsky and Berezovsky massifs are evidences that there existed a long-lived ore-forming magmatic system in the period from the late Cretaceous to Paleogene (47 – 67 Ma). The correlation of the data with those that have already been published earlier shows that by silica content the massifs’ rocks significantly correspond to types of classification of igneous rocks with minor geochemical variations [3]. Additional geological researches of rocks located in the vicinity of the intrusive massifs will allow features of magmatic and postmagmatic rocks of the Nizhnetaezhnny ore district to be characterized with more confidence.

6. References

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