OROGENIC VOLCANISM IN THE OPHIOLITE OCCURRENCE AREA IN NORTHWESTERN PERIPACIFIC

O.N. Ivanov (North-East Interdisciplinary Scientific Research Institute, 16 Portovaya St., Magadan 685000, Russia)

ABSTRACT

Within the Anadyr-Koryak geosystem, the late orogenic, significantly granitoid volcanism manifested itself through Eocene to early Miocene after the regional ophiolite stage in Neocomian. Discontinuous linear volcanic structure chains either have an inherited orientation of regional structures (the Penzhin-Algan belt) or trace lineaments dissecting the general structures (the Krasnoozersk-Opuk belt). In the first case, subvolcanic, plutonic domes and volcanic lava domes are composed of a basalt-andesite association. In the second case, volcanic depressional structures are made of rhyodacite-dacite, rhyolite-basalt, and potassium-rhyolite lava and pyroclasitc rocks. Volcanics belong to the hypersthene series of calc-alkalic range, featuring felsic-to-mafic development of volcanic structures and a greater sum of alkalic and, more importantly, potassium upwards in the section. Different geodynamic environments of volcanism resulted in different metallogeny, that is the Penzhin-Algan volcanic belt is dominated by Cu, Mo, and Au-Ag occurrences. The Krasnoozersk-Opuk belt is dominated by Au, Sn, Sb, and Hg occurrences.

The Anadyr-Koryak region in the northwestern section of the Peripacific is characterized by extensive ophiolite occurrences of different ages. The Late Jurassic-Early Cretaceous period of ophiolite formation ended with the early and late orogenic stages. The late orogenic stage (Eocene - Early Miocene) is represented by subareal volcanism of essentially granitoid composition. The Penzhina-Algan and Krasnoozersk-Opukh linear belts are formed of several separate volcano structures. These belts differ in formation, composition and metallogenic features. The magmatic complexes of these volcanogenic belts form a vertical succession of sodium, potassium-sodium, and potassium series.

The Anadyr-Koryak system in the northwestern Pacific is a continent-to-ocean transition zone. The regional structure consists of multistage Phanerozoic ophiolite troughs in heterogeneous Precambrian basement, which is composed of Archean (?) and Late Precambrian (R-Cm_1) complexes (Ivanov, 1992).

The prolonged development of these troughs include three stages of eugeosynclinal rejuvenation with associated formation of ophiolite assemblages. There were at least four stages of ophiolite formation recorded in the region. The first was in the latest Early Carboniferous followed by three Mesozoic stages; the Late Triassic, the Late Jurassic-Neocomian (Volgian to Hauterivian), and the Late Senonian (Campanian-Maastrichtian) stages. The first three stages terminated with plutonogenic ultramafite-gabbro-plagiogranite assemblages of ophiolite formation. During the Late Cretaceous stage, there was only a volcanogenic component of ophiolite troughs (Ivanov, 1993).

The Paleozoic, Late Triassic and Late Cretaceous trough-forming stages were incomplete, whereas the Late Jurassic-Neocomian stage terminated with a relatively complete set of early and late orogenic complexes. The early orogenic stage of Maastrichtian-Danian age is characterized at the base by a volcanogenic (basalt) molasse, followed by a complex of sub-sill bodies and dikes of alkalic dolerites (the Rarytkin complex), terminated with a high-granitoid, continuous gabbro-diorite-granodiorite-granite (sodium) series, and a granosyenite-monzodiorite-diorite assemblage of small intrusions.

The late orogenic stage of Eocene - Early Miocene age in the Anadyr-Koryak geosystem signified the onset of quite a new stage of magmatism that was associated with granitoid magmatic processes and manifested in volcanogenic facies. By the end of the early orogenic stage, ophiolite magmatism that occurred in Paleozoic and early Mesozoic time, was evidently replaced by a high-granitoid magmatism.

During the Eocene-Oligocene and Early Miocene, geodynamic, tectonic and paleogeographic environments were characterized by general regional structural compression and uplift, with intense landscape dissection. The formation of uplifts and depressions resulted in the deposition of sharply alternating facies and thicknesses, and formation of volcanic fields and chains. Concurrent with structural deformation and geomorphic changes, inland seas in intra-continental lows became smaller, shallower and more brackish lakes. In these residual lows, alternating transgressive and regressive facies, and later continental sediments were deposited. Early Cenozoic subaerial volcanism was not influenced by these processes as evidenced by various paragenic combinations of marine, continental and volcanogenic formations. These rocks indicate an obvious general continent-to-ocean transition of volcanic processes during the Eocene-Oligocene and Early Miocene.

During this time, volcanism proceeded within the Penzhina-Algan and Krasnoozersk-Opukh volcanic belts as linear chains of separate oval-shaped or elongated volcanic structures (Fig.1).

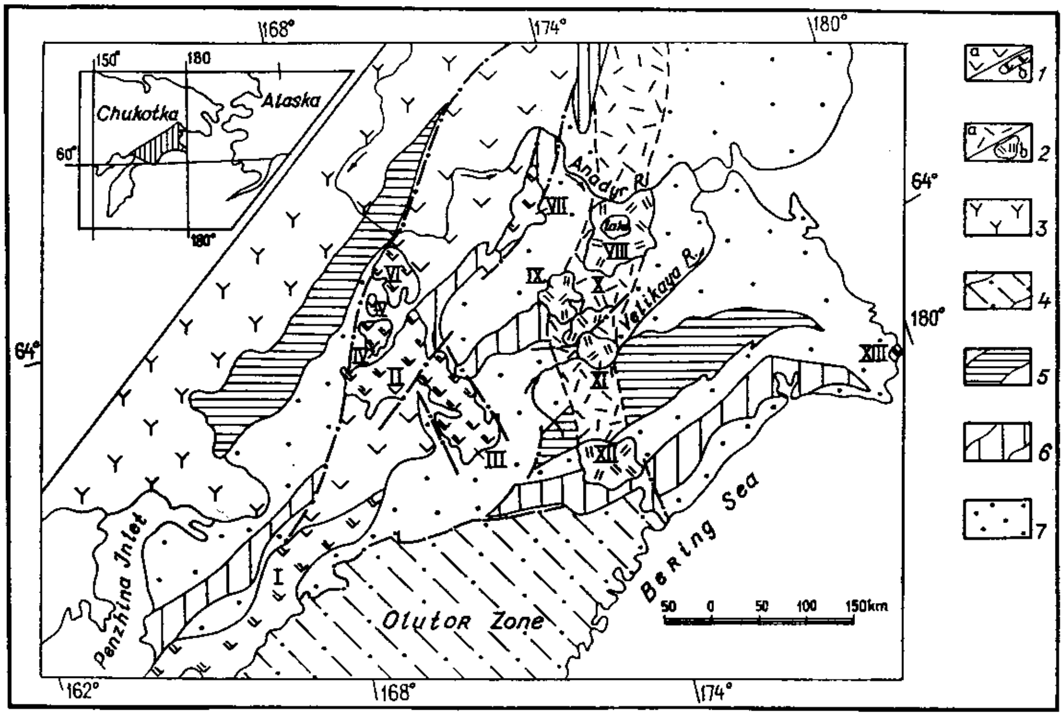

Fig.1 - Location map of late orogenic volcanic belts of the Koryak Highlands.
1 - the Krasnoozersk-Opukh volcanic belt (a) and (b) - volcanic structures; 2 - the Penzhina-Algan volcanic belt (a) and (b) - volcanic structures; 3 - the Okohtsk-Chukchi volcanic belt (non differentiated). 4 - Olutor zone. Major structures of the Anadyr-Koryak geosystem: 5 - marginal and median island arc; 6 - ophiolite through; 7 - non differentiated deposits (Pz-P). Major structures of late orogenic belts: I - Ichigin-Unevayam, II - Slautno-Main. III - Nutovakly-Kuibiveem, IV - Nalgim, V - Orlovka, VI - Russkogorsk, VII -Main-Algan, VIII - Krasnoozersk, IX - Lamut, X - Parkhonai, XI - Elekai, XII - Opukh, XIII - Navarin Cape

The Penzhina-Algan belt is the northeastern end of the Koryak-Kamchatsk volcanogenic belt (Filatova, 1988) and is predominantly located within the Penzhin trough that underwent an inversion during Eocene-Oligocene time. The belt is about 700 km long and 60 km wide. The southwestern flank of this belt consists of the Ichigin-Unevayam volcanic structure, which is nearly 250 km long and 40-50 km wide. The Ichigin-Unevayam volcanic edifice is made up of the Uney volcanic complex of felsic intrusives and the Ichigin subvolcanic andesitoid complex. The formation of these complexes was nearly contemporaneous (Khvorostov and Zaitsev, 1983). The Slautno-Mainskaya volcanic structure is 150 by 75 km long and consists of a cryptovolcano and a system of stocks and cross-cutting subvolcanic bodies, which form a plutonic dome structure. In its northern part, lava flow facies are intermittently present. The Kuibiveem (Nutovakly-Kuibiveem) volcanic depression of Oligocene-Miocene age measures 40 km by 80 km long and consists of two separate but genetically related volcanic fields. The southern Kuibiveem field is dominated by pyroclastic facies and the northern Nutovakly field is dominated by lavas. In the west, the depression is contains andesites, with rare dacite flows in the upper portion of the section. In addition, there are subvolcanic dolerite, extrusive diorite and granodiorite-porphyry bodies. In the east, this structure is composed of predominantly of dacites with rare basalt flows on mountain tops, and conglomerates at the base and throughout the section.

The next group of volcanic features includes the Nalgim, Orlovkin and Russkogorskaya structures, which belong to a major (90 by 30 km) shield volcanic edifice with central-type paleovolcanoes. The Nalgim and Ordovkin structures consist of extrusive bodies, sills, gently-dipping bodies of intermediate and mafic composition, and more rarely volcanic vent facies. Factors such as ring-fault structures and a framework of intersecting series of dikes and gently-sloping subvolcanic and extrusive bodies, result in a general plutonic-domal character of the structure (Fig.2). The Russkogorsk volcanic structure is dominated by multiflow facies, the position of which emphasizes the volcanic dome of Upper Oligocene-Miocene age (Apt et al., 1989). Analcite basalts occur as subvolcanic bodies and lava sheets in the upper portion of the Russkie Mts. and in the Main-Algan flank of this belt. In the opinion of the author, these analcite basalts are not related to the development of the discussed volcanic structures. The Main-Algan flank is a fragment of a volcanic dome, which is more than 100 km long and to 20 km wide. At its western edge, there are plutonic domes up to 20 km in diameter

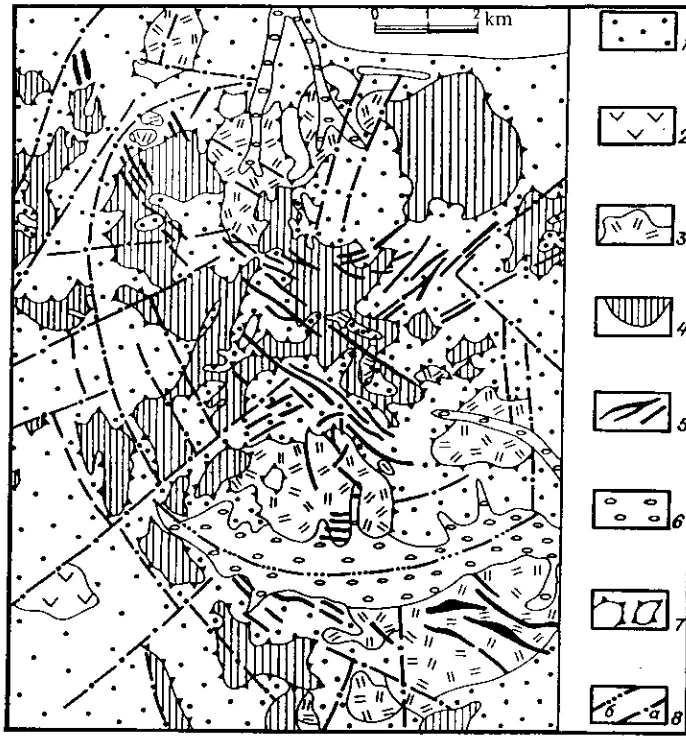

Fig. 2. Geologic map of central part of the Orlovka volcanogenic pluton-dome structure (composed by A.S.Bochkarev and V.I.Semenov, 1984-88). 1 - krivorechen suite (K_1a-K_2s)-monoclinally occurring stratum of conglomerate at the bottom (600 m), higher - stratum of conglomerates, gritstones, sands, siltstones (total 700-800 m). 2 - fragments of andesite covers of russkogorsk suit (Oligocene-Early Miocene). Series of subvolcanic bodies in the order of their formation from the early to late ones. 3 - rhyolites and rhyodacites; 4 - diorite, quartz-diorite porphyrites; in central portion of bodies - amphibole, in the periphery - with olivine and pyroxene; 5 - dike belts mostly of diorite and quartz-diorite composition, crossing the all previous rocks. The age of subvolcanic bodies and dikes is synchronous to russkogorskaya suit. 6 - Qaternary sediments; 7 - boundaries of volcanostructures and subvolcanic bodies. 8 - fault breaks a) established, b) supposed.

According to the ratio of the main rock types, the Penzhina-Algan belt structures are dominated by andesitoid rocks, with subordinate analcite basalts. Petrographically, this complex is characterized by the presence of hypersthene, even in felsic varieties of andesite assemblages containing important amounts of amphibole and biotite. This complex is dominated by dacite-andesite rocks, with subordinate mafic and felsic rocks.

Petrochemically, the rocks of this complex belong to the calc-alkalic-potassium-sodium series (Na_2O/K_2O= 3.2-4 with SiO_2=50-56%). Changes in the total alkalic sum are generally insignificant, although alkalinity is obviously decreased in rhyodacites. The basalt-andesite component generally lies within the subalkalic range, and dacite-rhyolite component features normal alkalinity (Fig.3). The sialic component is pertinent to high-alumina rocks, and andesite and especially andesite-basalt components are pertinent to moderate- to low-alumina and moderate- to high-titanic rocks (Fig.3, Table 1).

Changes in the total alkali and alumina sums and the potassium-to-sodium ratio, as well as, a successive replacement of the subalkalic and normal alkalic series of calc-alkalic range, are the result of antidromic volcanic development recorded in the given sections of volcanic structures.

The Penzhina-Algan volcanic belt features unique occurrences of mineral deposits that differ in their size, composition, and genetic complexes. The Ichigin-Uney structure of the southern flank of this belt contains gold-silver occurrences of the Ichigin complex and silver-tin occurrences of the Unevayam complex. The Nalgin, Orlovkin and Russkogorsk volcanic structures and the southern portion of the Main-Algan structure contain copper-molybdenum and gold-silver occurrences, which reveal a well-defined vertical zoning; only gold-silver mineralization is present in the Russkogorskaya volcanic structure where there are flow facies. The Main-Algan volcanic structure contains sulfide copper, mercury (quartz-dickite type), silicate-cassiterite, and presumably gold-quartz occurrences.

The Krasnoozersk-Opukh belt is tectonically independent of the other structural series and evidently cross-cuts major structures of the Koryak Highlands, including the Algan Block, the Mainits ensimatic middle island arc, and the Pikasvayam-Khatyrsky multistage trough, which testifies to its submeridional lineament. The length of this belt is about 300 km and width 30-40 km.

The Krasnoozersk volcanic depression is 100 long by 45 km wide and consists of intermediate-to-felsic volcanic flows inclined towards the center. It is bounded on the west by a chain of subvolcanic bodies. The section terminates with a contrasting rhyolite-basalt complex, which is not present in the Penzhina-Algan belt and includes a particularly high-potassium and subalkalic rhyolitoid rock member occurring in high-sodium basaltoids. The Lamut, Parkhonai, and Elekai volcanic structures are approximately of the same type and feature well-defined depressional structures, felsic-to-mafic development, and a particular dacite and rhyodacite rock composition, with wide-spread pyroclastic facies, including pumiceous lavas. The Opukh structure includes two approximately contemporaneous volcanic depressions dominated by dacite and basalt-andesite rock compositions. The dacite volcanic structure consists mostly of block-agglomerate tuffs. Rocks composing the volcanic structures of the Krasnoozersk-Opukh belt belong to dacite-rhyolite assemblages, including terminating rhyolite-basalt and rhyodacite ignimbrite complexes.

Table 1. Chemical composition of basalt-andesite complex rocks of the Penzhina-Algan volcanic belt.

Oxides	1(19)	2(9)	3(20)	4(10)	5(40)	6(43)	7(7)
SiO_2	50.56	50.98	56.42	53.83	60.67	64.93	71.07
TiO_2	1.99	2.01	1.15	1.44	0.91	0.59	0.26
Al_2O_3	14.90	15.36	15.86	16.98	16.23	16.11	15.36
Fe_2O_3	12.10*	4.67	7.69*	2.70	5.71*	3.54	1.35
FeO	-	4.79	-	5.15	-	0.54	1.01
MnO	0.18	0.14	0.14	0.12	0.06	0.06	0.05
MgO	7.70	6.88	5.19	5.98	2.71	2.13	0.65
CaO	8.06	7.61	7.13	7.62	5.48	4.19	1.87
Na_2O	3.96	4.00	3.86	4.12	4.16	4.28	4.48
K_2O	0.97	1.19	1.20	1.09	1.60	1.58	2.06
P_2O_5	0.31	-	0.26	-	0.31	0.13	0.10

Note: 1 - subalkalic basalt, 2 - trachybasalt, 3 - andesibasalt, 4 - trachyandesibasalt, 5 - andesite, 6 - dacite, 7 - rhyodacite. 2,4 - samples from collection of Zakharov and Glazunov (1987). Figures in brackets show the number of sample analyses.(*) is the total Fe_2O_3 determinated by ARL-72000 quantometer.

Table 2. Chemical composition of rocks of the Krasnoozersk-Opukh volcanic belt.

Oxides	1(5)	2(11)	3(27)	4(42)	5(86)	6(25)	7(25)
SiO_2	51.7	55.70	58.70	62.0	65.84	70.0	75.30
TiO_2	1.57	1.07	0.97	0.80	0.66	0.48	0.20
Al_2O_3	17.8	17.5	17.6	17.10	15.96	15.3	12.90
Fe_2O_3	9.27*	7.30*	7.55*	5.47*	4.31*	2.91*	1.44*
FeO	-	-	-	-	-	-	-
MnO	0.14	0.11	0.10	0.08	0.06	0.03	0.02
MgO	5.88	4.56	3.36	2.75	1.70	0.79	0.24
CaO	8.57	7.39	6.47	5.28	3.86	2.25	0.91
Na_2O	3.74	3.99	4.09	4.26	4.22	4.10	3.29
K_2O	0.65	1.0	1.19	1.43	2.20	30.8	4.40

Note: 1 - basalt, 2 - andesibasalt, 3 - andesite, 4 - andesidacite, 5 - dacite. Rhyodacite-rhyolite complex: 6 - rhydacite, 7 - rhyolite.

Hypersthene is present in all rocks of this complex, even in rhyolitoid ignimbrites and hyalosrhyolites to dacites; there are also scarce sporadic biotite and amphibole occurrences testifying to a pulse-like supply of fluids into the melt, i.e. water.

The volcanic structures of the Krasnoozersk-Opukh belt described above are composed of dacite-rhyolite rock assemblage with unimportant basalts and andesites. The felsic rocks here belong to calc-alkalic potassium-sodium series of normal alkalinity with a widely changing sum of potassium and sodium oxides (Table 2). A contrasting rhyolite-basalt assemblage in high-sodium rocks of mafic composition is distinguished by a member of potassium dacites and rhyodacites (Table 3). The section is terminated with rhyodacite-rhyolite ignimbrites in the high-potassium range (Table 2).

Table 3. Chemical composition of rocks of contrast rhyolite-basalt complex.

Oxides	1(9)	2(6)	3(5)	4(9)	5(25)
SiO_2	51.99	54.09	58.48	65.88	72.76
TiO_2	1.61	1.16	1.10	0.72	0.18
Al_2O_3	16.29	17.32	17.34	15.72	13.01
Fe_2O_3	9.41*	7.33*	4.17	2.69	1.44
FeO	-	-	3.06	2.28	0.50
MnO	0.15	0.11	0.05	0.05	0.06
MgO	4.12	4.16	2.95	1.05	0.33
CaO	9.16	8.42	5.99	2.74	0.90
Na_2O	3.11	3.71	4.12	4.28	3.43
K_2O	0.88	0.99	1.13	3.19	4.52
P_2O_5	0.19	0.14	0.22	0.15	-

Note: 1 - basalt, 2 - andesibasalt, 3 - andesite, 4 - dacite, 5 - rhyolite. (*) is the total Fe_2O_3 determinated by quantometer.

Table 4. Chemical composition of Navarin complex basalts.

Oxides	1	2(11)	3(17)	4(9)
SiO_2	42.40	47.04	45.97	44.61
TiO_2	3.50	1.97	2.23	2.36
Al_2O_3	14.00	16.06	14.18	14.10
Fe_2O_3	9.00	3.24	4.61	3.78
FeO	7.80	6.84	6.89	7.94
MnO	0.27	0.21	0.19	0.15
MgO	6.80	7.43	9.28	13.14
CaO	10.55	9.18	9.43	9.44
Na_2O	2.84	3.41	3.91	3.17
K_2O	0.42	0.91	1.89	1.33
Na_2O/K_2O	6.76	3.96	2.19	2.23

Note: Subalkalic rocks 1 - ferrobasalts, 2 - leicocratic basalt, 3 - olivine basalts, 4 - ankaramites.

The metallogeny of this belt is not clear in detail. Besides realgar-orpiment mineralization, there may be also antimony and silver mineralization, and placer occurrences of multicoloured cassiterite and fine gold are found.

In the Cenozoic, volcanism of the regional deuterogenic stage terminated with the Navarin basalt complex of supposedly Pliocene-Pleistocene age. Subalkalic olivine and high-magnesian basalts of potassium sodium range and ankaramites (Table 4), contain numerous fragments (or nodules?) of olivenites, wehrlites, and plagioclase-bearing lherzolites (Fedorov and Seregina, 1990; Zanyukov et al., 1976).

Thus, the multistage ophiolite history of the Anadyr-Koryak geosystem terminated with a essential granitoid volcanic magmatism during the late orogenic stage. At that time, the volcanic processes occurred under different tectonic, paleogeographic and geodynamic environments. It is noteworthy, that there are huge volumes of volcanic, predominantly granitoid, rocks compositionally dominated by sodium oxide, which predetermined the regional petrochemistry since Archean (?) to Cenozoic.

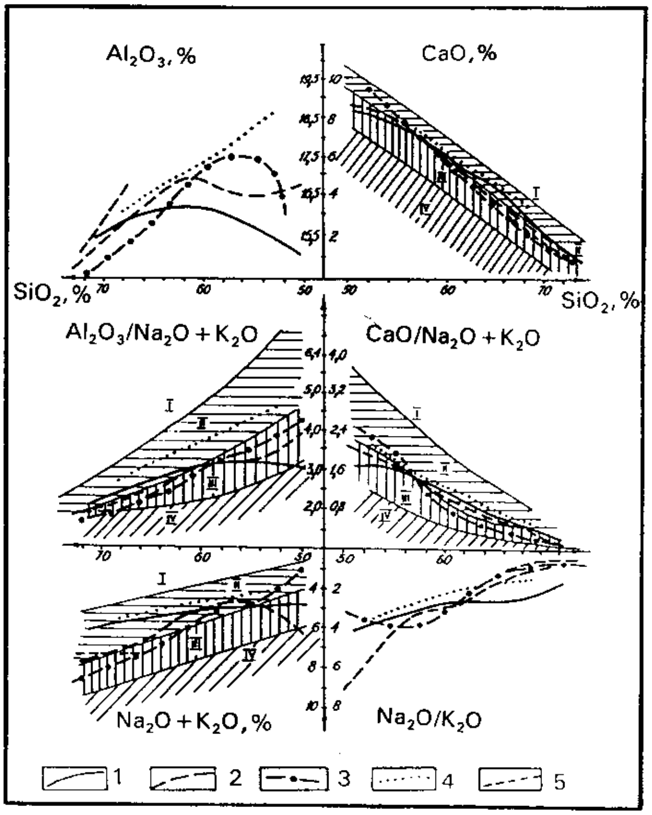

Fig. 3. The rock petrochemical chart for the Cenozoic late orogenic volcanic complexes of the Koryak Highlands.
Areas of distribution of petrochemical series: I - calcareous, II - calc-alkalic, III - subalkalic, IV - alkalic. Variety curves: 1 - andesitoid complex of the Penzhina-Algan volcanic belt, 2 - rhyolite-dacite complex, 3 - rhyolite-basalt complex of the Krasnoozersk-Opukh volcanic belt, 4 - volcanic series of the Okhotsk-Chukchi volcanic belt.

According to extensive petrographic data, all volcanogenic complexes under consideration belong to the hypersthene rock series. The evidence of this series is wide-spread and persistent, thus testifying to deep sources of magmatic processes, the regional character of which is not in fact influenced by the geologic setting of Phanerozoic structures nor the regional basement.

The late orogenic granitoid volcanic magmatism of successive sodium, potassium - sodium and potassium series corresponds to the continental crust and presents convincing evidence of a quite different composition and state of the crust with reference to the ophiolite past.

The combination of ophiolite (Pt, Cr, Au), early orogenic (Au, Sb, As, Mo) and late orogenic (Sn, Au, Ag, Hg, Sn) mineralization, provides for optimistic forecasts for the Koryak Region.

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