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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

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◆

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

◆

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PROBLEMS OF PETROLOGY OF ULTRAMAFIC ROCKS OF KARATURGAY RIVER BASIN, NORHTERN ULYTAU (CENTRAL KAZAKHSTAN)

> «Only by synthesizing all the sciences
> of the Earth can we find the "truth".»
> *Alfred Wegener*

Abstract. The paper is dedicated to major aspects of petrology and metallogeny of mafic and ultramafic rocks of Northern Ulytau Range. The Karatugay Complex is introduced for hypabyssal diabase-picrites of the Western Ulytau Belt. They are considered as products of spinel peridotite melting, which makes them different from the Lower-Paleozoic upper-subduction ophiolite complexes of Central Kazakhstan, the products of garnet lherzolite melting. The rock-forming and accessory mineral contents for picrites and picritic diabases are given. A presence of apopicritic olivine, which is the outmost member of the picrite-diabase sequence, and a presence of pure larnite does not exclude their origin as a result of high-calc larnite melts differentiation, while composition of these melts could approach that of kimberlites. Obtained geochemical signatures suggest that the Karaturgai Complex was derived from Ti and Cr depleted mantle melts, which were enriched with (Cu-Ni)+(Zn-Pb)+PGE, REE (Y, La, Yb) and also lithophylic elements (Zn, Sr, Ba). Intrusion of the hypabyssal Karaturgai Complex occurred during the ongoing collision of the suspect terranes presently incorporated into the tectonic collage of the Ulytau Megaterrane, probably, at the time of the assemblage of the Rodinia Supercontinent.

Key words: Ulytau, Kazakhstan, picrite basalts, diabases, copper–nickel sulfide ores, pallidum, platinum, Neoproterozoic.

Introduction to the questıon. In the west of Central Kazakhstan in the Ulytau mountains, the mafic and ultramafic rocks were known for a long time in the Precambrian metamorphic strata, the spatial and genetic connection with them of chrysotile-asbestos, sulfide copper-nickel mineralization for a long time predetermined interest in their study [1-12].

For the first time picrites and apopycritic serpentinites within the Northern Ulytau were described in 1962 by Yu.L. Semenov [5] on the right bank of the river. Karaturgai (figure 1) and separated from the Western Ulytau "ophiolite belt" into an independent karaturgay diabase-picrite complex. Based on the analogy with other development regıons of diabase-picritic complexes, they suggested that picrites and diabases Northern Ulytau rıdge are in genetic connection with the development of early Mesozoic basalt magmatism of the Turgai arch. N.P. Mikhailov, Yu.L. Semenov [5] first noted the spatial and genetic relationship of copper and nickel sulphides with picrites.

In 1967, I.I. Vishnevskaya and I.F. Trusova in the article "West Ulutavıan belt of ultrabasic and basic rocks" criticized the ideas of N.P. Mikhailova and Yu.L. Semenov and carried the sills of the picrits of the

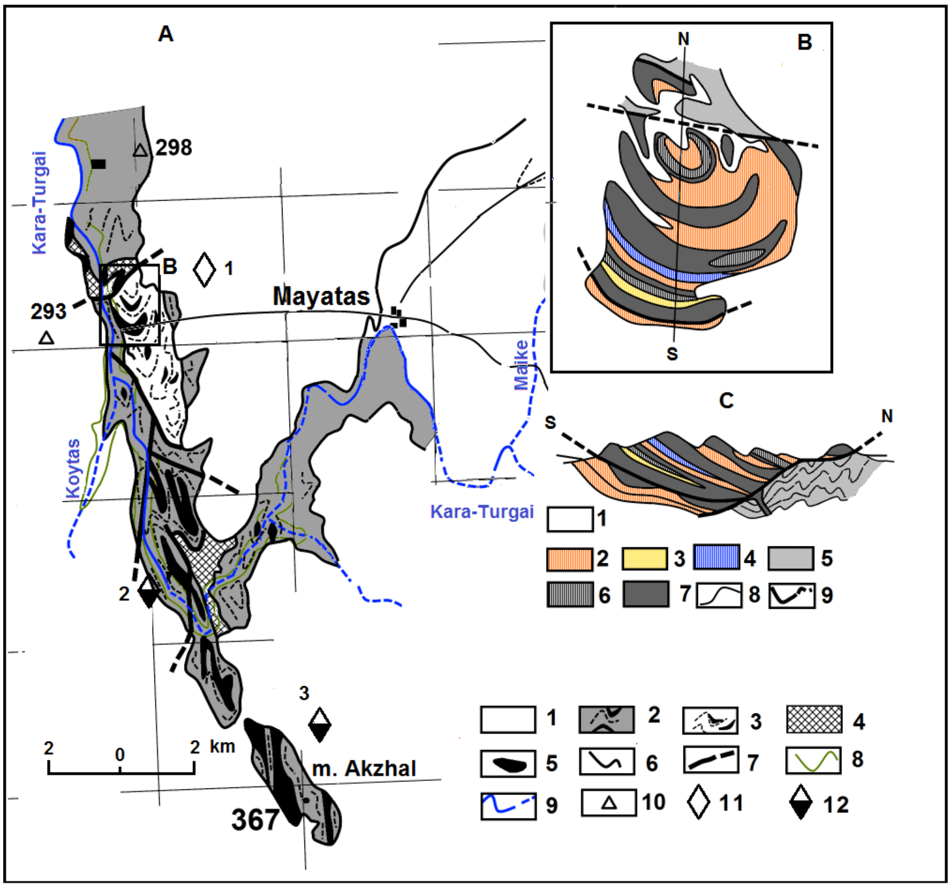

Figure 1 –

A – Scheme of the geological structure of the area of the middle reaches of the river Kara-Turgai by I.I. Vishnevskaya and I.F. Trusovoy [6], S.S. Chudin [13] with the changes and additions of the authors.

1 - Cenozoic deposits; 2-3 - the Karsakpay series (mesoproterozoic): 2 - the stratum of metabasalts, less often of andesites with subordinate horizons of muscovite-quartzite and quartzite shales, 3 - the stratum of variegated tuffs of quartz albitophyres and ash banded tuffs of medium composition; 4 - muscovite-albite and graphite schists, albite gneisses and microgeans of the Aralbaia series (PR1ar); 5 - Karaturgai diabase-picritic complex (PR3 k); 6 - geological boundaries; 7 - tectonic disturbances; 8 - topographical isolines; 9 - the river Kara-Turgai and its tributaries Koitas and Maike; 10 - trigonometric heights. 11-12 - genetic types of minerals; 11 - magmatic group (liquation class), sulfide copper-nickel ores with platinoids and rare earth elements (Dy, Y, Ce) in picrites, 12-carbonatite group (fluid-magmatic class), copper sulfides with platinum and rare-earth elements (Y, TREE)).

Ore deposits: 1 - Karaturgai; 2 - North Akzhal; 3 - Eastern Akzhal.

The scheme of the geological structure of the Karaturgai Massif (B) and the section SN (C) through the central part of the massif are constructed from materials of NP. Mikhailova, Yu.L. Semenova [5], I.I. Vishnevskaya and I.F. Trusovoy [6], O.B. Beiseeva [12] with the changes and additions of the authors.

1 - Cenozoic deposits; 2-4 - Karsakpay series (PR2kr): 2 - tuffs of quartz albitophyres; 3 - banded tuffs of medium composition; 4 - tuffs of basic composition; 5 - graphite-albite schists of the Aralbaia series (PR1ar); 6-7 - Karaturgai diabase-picritic complex: 6 - quartz diabases, diabases; 7 - picritic diabases, picrites, apopyritic serpentinites, mainly spherical, porphyry; 8 - geological boundaries; 9 - discontinuous violations and thrusts.

Karaturgai complex to the intrusions of the gabbro-peridotite formation.At the same tıme, considering their paragenetic connection with the rocks of the spili-keratophyre formation widely known in the series of ophiolite belts of Central Kazakhstan [4], thus, they repeated the previously developed Yu.I. Polovinkina [2] formation sequence scheme of Southern Ulytau mafic-ultramafites. This point of view for many years was adhered, on the nature of the basic and ultrabasic rocks of the Northern Ulytau, by O.B. Beiseev [8, 12], R.M. Antonyuk [11], S.S. Chudin [13], A.B. Baybatsha [14].

However, it should be noted that the geological map compilers of the Kazakh SSR [10], one of whose authors was R.M. Antonyuk, united the main and ultrabasic rocks of the Western Ulytau "ophiolite belt" into the Beleutinsky complex of the Late Proterozoic gabbro, gabbro-diabase, which, as they noted, was first described in the Karsakpai region of IS. Yagovkin in 1927.

The authors [15] of this article share the point of view of N.P. Mikhailova and Yu.L. Semenova [5, 9] on the nature of the mafic and ultramafic rocks of the Western Ulytau belt, and in its composition there are two hypabyssal complexes: in the north - Karaturgai diabase-picritic, and in the south - Beleutinsky ferrogabbronorite-diabase-picritic.

In the absence of absolute age data, the time of formation of the Karaturgai complex was interpreted as Precambrian [16], then as a late Proterozoic [17, 10], then Ordovician [6] or early Mesozoic [5].

Below we shall consider in detail the petrologic and metallogenic features of Northern Ulytau diabase-picritic complex.

Structural position. All the researchers who studied the hypabyssal rocks of the Karaturgai complex, despite their disagreements about the genesis of the ultramafic rocks of the region [5, 6, 8, 10], had a common point of view on their structural position and the shape of the bodies.

Apopycritic serpentinites, picrites, picritic diabases, diabases and quartz diabases of the Karaturgai complex form small hypabyssal bodies, usually in the form of large and small interplastic deposits (see figure 1). Quite often the sills lie in the castles of the Neoproterozoic metamorphic strata of the Karsakpaia and Bozdak series, in single instances they form dikes in the Mesoproterozoic strata. Analogues of picrites and associated diabases in the composition of Ulytau rıdge Paleozoic stratum was not found.

Features of rock composition. Considering the extremely opposite points of view on the genesis and age of ultrabasic and basic species of the ridge Ulytau, the authors suggest from the standpoint of modern geochemical geodynamics to consider in more detail petrogeochemical features of the rocks of the Karaturgai complex and to determine their place in the geological history of the development of the west of Central Kazakhstan.

Below we will consider the composition of the most well-studied rocks of the diabase-picritic complex of the upper reaches of the river Sabasaldyturgai, the river basin Karaturgai, its tributary Koitas and Mount Akzhal (see figure 1).

Between apopycritic serpentinites, picrites, picrite diabases, diabases and quartz diabases, gradual transitions are noted. Picrites, picritic diabases and diabases have a well-pronounced porphyry and porous structure, a spherical and blocky separation.

Picrites are bright representatives of the complex rocks containing: olivine (65-75%), monoclinic and rhombic pyroxenes in equal amounts (5-7%), brown hornblende (2-4%), sossuritized plagioclase (10-15%), biotite, phlogopite (0.5%), sulphides (0.5-2%), manganoylmenite, titanogenate, magnetite, chrome spinel, apatite.

Picritic diabases do not differ in appearance from picrites, however, the quantitative ratios of minerals vary considerably. The content of olivine decreases (25-40%), the proportion of pyroxenes and plagioclase increases proportionally, respectıvely, and clinopyroxene predominates over orthopyroxene. The amount of sulfides and apatite significantly decreases, but the amount of chrome spinel, manganoylmenite and titanomagnetite increases.

Diabases and quartz diabases are met all over with picrites, often together in the same sila. From picrites, porphyritic diabases differ only in the absence of orthopyroxene. They include clinopyroxene (45-60%), plagioclase (33-40%), biotite (about 1%), quartz (1.5-2%), apatite and ilmenite. There are no sulfides.

A considerable part of the rocks of the complex is composed of porphyritic apopycritic serpentinites (peridotites). Serpentine (50-80%) is often represented by chrysotile and antigorite; rare relicts of orthopyroxene are rare; clinopyroxene relics (15-20%) preserved significantly better, pessimorphoses of sossurita are found rarely (2-3%), pseudomorphs of phlogopite lamellar crystals, sometimes horny the blend achieves 5%, apatite, pomegranate and ore minerals are also found that are less than 1% of the total mass. Quite often serpentine develops carbonate and talc.

A special group of rocks is formed by cores of carbonate rocks with sulphides, which were opened by a well Yu.I. Rylov in 1967 in Karaturgai river basin (manifestation of North Akzhal). A standart mineral composition, calculated from the silicate sample from these carbonate rocks, containing up to 5 wt. % alkali and 22.78 wt. % of calcium oxide, showed: nepheline (15%), wollastonite (19%), diopside (35%), larnite (28.56%) and apatite (1%), the rest being plagioclase and orthoclase. Such rocks can be referred to carbonate-silicate metasomatites (carbonatitoids). Sulphides are also found in quartz-carbonate-albite cores in the composition of amphibolites and apopycritic serpentinites of the East Akzhal developments.

Such zones of mineralization are accompanied by lithochemical halos of Nb, Y, Th and REE. Rare-earth elements (Y, La, Yb) and platinoids are also found in the picrites of the Akzhal massif.

Petrogeochemical characteristics. According to the nature of the accumulation of basic petrogenic oxides, the feldspathic picrites of the Karaturgai complex can be divided into two groups (table 1). The first group is represented by low-TiO_2 (0.54-0.74%), low-Al_2O_3 (3.67-5.34%) picrites and apopyritic serpentinites, whereas the picrites of the second group contain more TiO_2 (0.89-1.08%), Al_2O_3 (5.58-8.30%), and FeO (8.23%-5.9%) prevails over Fe_2O_3 (5.38-3.33%).

Apopycritic serpentinites of the first group of the upper reaches of the river Sabasaldyturgai in relation to those of the basin of the river Karaturgai is somewhat depleted of SiO_2 (37.7%), Al_2O_3 (3.67%), but at the same time it is somewhat enriched in FeOg (13.38%) and the ratio of the main petrogenic components is close to the meimechite composition, however, they are depleted by normative diopside (0.69%) at extremely high contents normative hypersthene (26.66%). While apopycritic serpentinites and picrites of Karaturgai rıver is slightly enriched in SiO_2 (<39.7%), Al_2O_3 (5.34%), TiO2 (<0.64%), alkalis (<0.74%) and FeO_2 (12.85%) depleted, with Fe_2O_3 predominance (7.96-5.61%) over FeO (6.22- 3.3%).

The number of normative diopside, olivine naturally grows ın them and the amount of normative hypersthene can fit, both of which obey the picritic trend (see figure 2, A). This is also clearly demonstrated by the Al_2O_3/TiO_2-CaO/Al_2O_3 diagram (see figure 2, B), where their figurative points lie in the field of ferro-picrites.

On the statistical diagram of S.D. Chetverikov [25] some of their figurative points are shifted to the area of lherzolites and verlites, while the amount of normative diopside decreases, but the fractionation index (up to 25.6) and correspondingly the amount of normative olivine grows.

A special group consists of low- Al_2O_3/TiO_2/FeOpot apopycritic serpentinites corresponding to the mineral composition of olivinites, in which the normative olivine is more than 90% (table 1, No. 7.8). Apopicritic olivinites with normative larnitis are rare (high-temperature monoclinic polymorphic analogue of calcioolivin or monticellite).

In the picrites of the second group (table 1, No. 9-14), the level of SiO_2 (39.86-45.63%), TiO_2 (0.87-1.08%), Al_2O_3 (5.58-8.30%) gradually increases, the amount of MgO (<30.0%), Cr_2O_3 (<0.25%) decreases with the predominance of FeO (8.23-5.9%) over Fe_2O_3 (5.38-3.33%).

In the picritic diabases (table 1, No. 15-17), the role of SiO_2 (44.92%), Al_2O_3 (10.9-11.7%), TiO_2 (1.24-1.58%) and Na_2O (1.45-2.45%) increases, but the level of MgO (11.5-17.33%) decreases with a constant predominance of FeO (9.65-6.89%) over Fe_2O_3 (5.66-5.16%). In the diagram $TiO_2 \cdot 10$-Al_2O_3-MgO (see figure 2, A), their figurative points continue the picritic trend.

Diabases and quartz diabases (table 1, No. 18-22) are enriched with SiO_2 (> 47.32%), Al_2O_3 (<14.45% 5), TiO_2 (1.88-2.25%), the role of Na_2O (2.03-2.35%) K_2O (0.25-0.76%) and P_2O_5 (up to 0.25%) sharply increases in them, relative to picrites. With respect to picrites, the amount of normative ilmenite increases (up to 2.85%).

According to the nature of the accumulation of iron, they are typical high-iron toleites, and on the discriminative diagram of the $TiO_2 \cdot 10$-Al_2O_3-MgO ratios (see figure 2, A), their figurative points are located in the field of the picritic series, their ratio of Al_2O_3/TiO_2 CaO/Al_2O_3 (see figure 2, B) indicate relationship with picrites.

According to the results of spectral semiquantitative analysis [5], the picrits of the Karaturgai complex are enriched with incompatible (Sr, Ba, Zr) and compatible (Ni, Co, V, Sc) elements, and also have high concentrations of elements with highly charged ions (Zr, Y). По According to Yu.I. Rilov and co-authors (1967) in the apopycritic serpentinites of the Akzhal massif, the level of concentration of compatible (coherent) elements reaches (g / t): Ni (3000), Cr (3000), Co (300), V (300), Sc (10) , they also contain higher concentrations of rare earth elements (g / t): Y (1000), Yb (30), La (200), they are listed among the chalcophile elements (%): Cu (0.02), Pb (0.006), Zn (0.03). It should be noted that in the zones of crushing of serpentinized picrites of the Akzhal massif, the Y concentration level reaches 0.2%.

High concentrations of incompatible and compatible, as well as rare-earth elements show a low degree of fractionation of the mantle substance against the background of their depleted titanium.

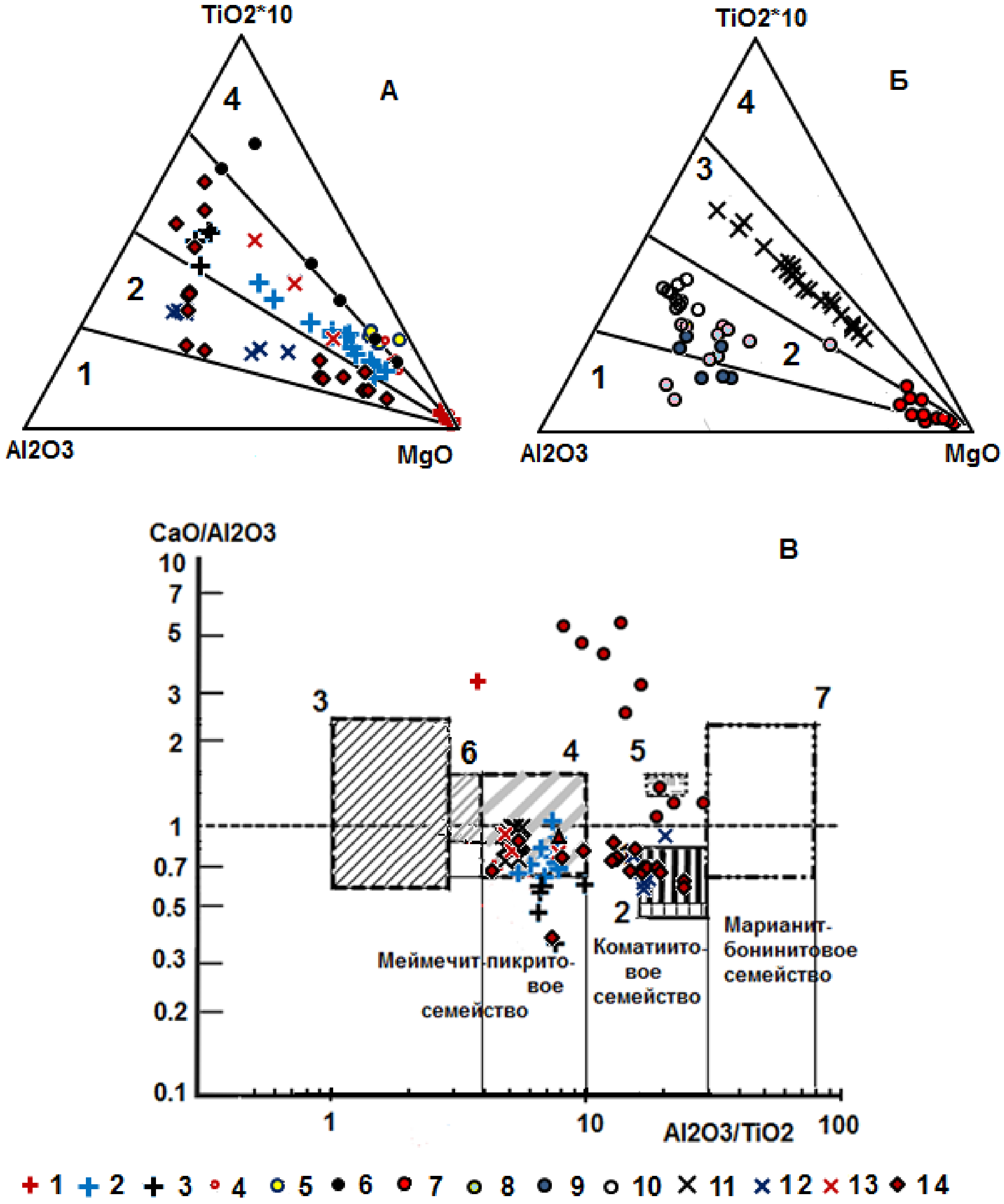

Figure 2 –

A, Б – Diagram of $TiO_2 \cdot 10$-Al_2O_3-MgO, wt. % [18].

Fields of volcanic series: 1 - boninitic, 2 - komatiite, 3 - picritic, 4 - alkaline-ultramafic.

1-3 - Karaturgai diabase-picritic complex [5, 6 and unpublished data Yu.I. Rylova (1967-1971)]: 1 - low-Ti apopycritic serpentinites, 2 - picrites, 3 - quartz diabases; 4-6 - rocks of the Pechenga region [19, tab. 67]: 4-5 - non-ore: 4 serpentinized olivinites and 5 - serpentinized verlites; 6 - rocks of the gabbro-verlite nickel complex; 7-10 - rocks of the Karaulshakin paravoctochon [20, 21]: 7 - cumulative peridotites (verlites and lherzolites), 8 - gabbro, 9 - guardulites and magnesian diabases, 10 - quartz diabases of the spilite-keratophyre complex; 11 - picrits of the Hawaiian plume [22]; 12-15 - magnesian rocks of the Norilsk plume [23]: 12 - Tuklonskaya and Nadezhdinskaya suites, 13 - of the Gudchikhin suite, and 14 - of the Maslovskaya intrusion.

B – Diagram of Al_2O_3/TiO_2 (ATM) – CaO/Al_2O_3 [24].

Vertical lines - borders of petrochemical series on ATM.

Komatite family: 1 - komatiite peridotites and dunites, 2 - komatiites, 5 - low-titanium picrites.

Meimechit-picritic family: 3 - meimechita, 4 - ferro-picrites, 6 - picrites.

Marianite-boninite family: 7 - marianites.

Table 1 – Chemical and regulatory composition of the rocks of the Karaturgai complex

#	1	2	3	4	5	6	7	8	9
Rocks	Picrites of Type I							Picrites of II Type	
SiO_2	37.7	39.5	39.7	42.34	40.54	47.42	41.25	39.86	43.72
TiO_2	0.56	0.64	0.54	0.59	0.74	0.72	1.02	0.89	1.02
Al_2O_3	3.67	5.01	5.34	4.52	4.97	5.14	6.13	6.13	5.58
Cr_2O_3	0.39	0.25	0.30	0.25			0.15		
Fe_2O_3	7.96	7.84	6.65	9.15	8.37	5.61	5.38	4.14	3.33
FeO	6.22	5.01	5.51	4.77	3.3	5.74	8.12	8.23	7.4
MnO	0.17	0.09	0.1	0.2	0.16	0.18	0.14	0.21	0.17
MgO	29.06	30.03	30.25	27.05	30.13	25.4	27.16	28.57	26.75
CaO	2.09	3.53	3.25	3.31	2.97	2.01	4.46	3.99	3.7
Na_2O	0.06	0.51	0.17	0.17	0.37	0.11	0.65	0.53	0.14
K_2O	0.03	0.23	0.15	0.01	0.23	0.09	0.24	0.24	0.11
P_2O_5									0.11
$H2O^+$	12.19	7.24	7.76	7.62			5.25	6.64	7.89
$H2O^-$	0.50	0.52	0.48	0.46			0.50	0.46	0.26
П.п.п.		0.24	0.38	0.04	8.66	7.34			0.11
Amount	100.60	100.72	100.47	100.47	100.44	100.39	100.50	99.86	100.18
Fe_2O_3/FeO	1.3	1.6	1.2	1.9	2.5	<1.0	0.7	0.5	0.5
FeO/MgO	0.21	0.17	0.18	0.18	0.11	0.23	0.30	0.29	0.28
CaO/Al2O3	0.57	0.70	0.61	0.73	0.60	0.40	0.73	0.65	0.66
Al_2O_3/TiO_2	6.55	7.83	9.89	7.66	6.72	7.14	6.00	6.89	5.47
Ni		0.19	0.14	0.08					
Co		0.004	0.003	0.004					
Ni/Co		47.5	46.7	20.0					
Mg#	79.5	81.6	82.4	78.2	83.2	80.8	78.9	81.0	82.1
Pl	14.22	19.72	19.41	17.11	18.88	14.23	23.73	23.40	19.93
Ort	0.23	1.89	1.21	0.08	1.88	0.76	1.88	1.95	0.90
Cor						1.08			
Di	0.69	5.93	2.43	4.33	3.06		7.61	5.24	2.87
Hy	26.66	8.79	18.89	37.85	20.30	73.68	12.61	9.99	44.74
Ol	55.75	61.42	56.02	38.28	53.62	8.03	51.37	56.86	28.43
Ilm	0.86	0.92	0.77	0.85	1.06	1.03	1.41	1.25	1.69
Mt	1.59	1.33	1.28	1.51	1.20	1.18	1.39	1.31	1.15
Ap									0.28
Diff.I.	14.5	21.6	20.6	17.2	20.8	15.0	25.6	25.4	20.8
Elt	1334	1341	1331	1284	1314	1185	1327	1340	1259
EH_2Oc	0.13	0.12	0.13	0.19	0.15	0.50	0.13	0.12	0.25

Table 1 (continuation 1)

#	10	11	12	13	14	15	16	17	18	19	20
Rocks	Picrites of II type			Picrite diabases			Diabases				
SiO_2	45.63	44.04	44.14	42.82	44.92	49.9	47.48	47.32	47.84	48.53	47.85
TiO_2	1.08	1.08	0.94	1.58	1.4	1.24	1.88	1.88	1.94	2.1	2.25
Al_2O_3	7.1	8.3	6.93	11.7	11.0	10.9	14.45	14.39	12.63	13.68	13.7
Cr_2O_3					0.10						
Fe_2O_3	3.83	4.47	3.77	5.66	2.16	3.97	5.25	1.03	5.8	2.37	2.5
FeO	6.55	6.86	5.90	7.97	9.65	6.89	9.78	14.69	9.21	8.29	10.42
MnO	0.11	0.18	0.18	0.0	0.15	0.17	0.15	0.18	0.22	0.16	0.19
MgO	25.24	20.97	23.7	15.23	17.33	11.5	6.15	6.12	6.45	7.56	6.27
CaO	3.38	7.39	7.15	8.97	7.6	8.9	10.67	10.48	10.36	10.51	11.12
Na_2O	0.08	0.34	0.15	2.45	1.45	2.0	2.23	2.35	2.11	2.03	2.16
K_2O	0.08	0.08	0.08	0.72	0.2	0.92	0.25	0.44	0.27	0.76	0.64
P_2O_5	0.14				0.18	0.38				0.23	0.25
$H2O^+$	6.79				3.92		2.00	1.64		3.29	2.42
$H2O^-$	0.20				0.28		0.28	0.30		0.28	0.11
П.п.п.	0.14	7.69	6.90	3.08	0.18	2.20			2.91	0.23	0.25
Сумма	100.21	101.40	99.84	100.18	100.47	99.20	100.57	100.82	99.74	99.79	99.88
Fe_2O_3/FeO	0.6	0.7	0.6	0.7	0.2	0.6	0.5	0.1	0.6	0.3	0.2
FeO/MgO	0.26	0.33	0.25	0.52	0.56	0.6	1.59	2.40	1.43	1.10	1.66
CaO/Al2O3	0.48	0.89	1.03	0.77	0.69	0.82	0.74	0.74	0.82	0.77	0.81
Al_2O_3/TiO_2	6.57	7.69	7.40	7.41	7.86	8.79	7.69	7.45	6.51	6.51	6.09
Ni					0.13		0.003	0.002			
Co					0.002		0.001	0.003			
Ni/Co					65.0		3.0	0.7			
Mg#	82.0	77.4	82.0	67.5	72.7	66.2	43.0	43.4	44.4	56.4	46.9
Pl	20.96	29.81	24.36	31.55	42.51	41.41	55.68	55.49	50.51	50.74	51.72
Ort	0.68	0.67	0.67	5.36	1.52	6.76	1.86	3.21	2.02	5.57	4.69
Neph				8.99							
Cor	0.93										
Di		13.21	14.80	20.35	10.87	17.40	18.93	19.15	21.73	19.19	21.61
Hy	57.84	30.78	32.32		16.79	26.47	14.26	10.83	20.79	20.21	14.62
Ol	16.65	22.88	25.56	30.40	24.87	3.94	5.46	7.54	0.99		2.69
Ilm	1.51	1.49	1.30	2.04	1.83	1.58	2.38	2.38	2.51	2.67	2.85
Mt	1.08	1.17	1.0	1.31	1.17	1.03	1.43	1.40	1.45	1.03	1.25
Ap	0.35				0.43	0.87				0.53	0.58
Diff.I.	21.6	30.5	25.0	45.9	44.0	48.2	57.4	58.7	52.5	56.4	56.4
Elt	1233	1266	1257	1318	1272	1184	1241	1241	1220	1205	1228
EH_2Oc	0.32	0.23	0.25	0.14	0.22	0.51	0.29	0.29	0.36	0.42	0.33

Note. The rocks of the picrite-diabase complex.1, 7, 8- [5]; 2-4, 9, 10, 14, 16, 17, 19, 20 - [6]; 5-6, 11-13, 15, 18 - Yu.I. Rylov, 1967, 1971.

Table 1.1 – Chemical and regulatory compositions of apopycritic serpentinites (21-28), carbonatitoid (29) of the Karaturgai complex

#	21	22	23	24	25	26	27	28	29
SiO_2	32.54	35.96	11.82	33.86	35.28	32.66	33.86	35.28	32.10
TiO_2	0.08	0.08	0.08	0.16	0.0	0.04	0.16	0.08	1,80
Al_2O_3	0.10	0.67	0.45	0.70	0.30	0.59	0.70	0.3	13.54
Fe_2O_3	5.39	4.34	6.25	8.60	6.69	9.62	8.60	6.69	9.00
FeO	0.70	0.28	0.32	0.82	1.60	1.75	0.82	1.6	3.62
MnO	0.0	0.0	0.0	0.0	0.10	0.14	0.1	0.1	0.28
MgO	31.13	37.14	41.14	39.25	40.68	39.79	39.25	40.68	7.45
CaO	8.04	2.47	1.24	0.46	0.93	0.31	0.46	0.93	25.51
Na_2O	0.06	0.08	0.06	0.04	0.04	0.04	0.04	0.04	0.10
K_2O	0.04	0.06	0.04	0.04	0.02	0.02	0.04	0.04	0.04
П.п.п.	18.76	17.48	38.10	14.04	13.71	13.29	14.04	13.71	6.92
Amount	96.84	98.56	99.50	97.97	99.35	98.25	97.97	99.36	100.36
Fe_2O_3/FeO	7.7	15.5	19.5	10.5	4.2	5.5	10.5	4.2	
FeO/MgO	0.02	0.01	0.01	0.02	0.04	0.04	0.02	0.04	
CaO/Al_2O_3	80.4	3.7	2.7	0.7	3.1	0.5	0.66	3.10	
Al_2O_3/TiO_2	1.3	8.3	5.6	4.4	-	14.8	4.38	3.75	
Mg#	91.7	94.6	93.2	90.1	91.4	88.3	89.1	90.5	55.7
Pl		2.95	1.20	2.85	1.34	1.95	2.86	1.24	44.14
Ort		0.38		0.38	0.15		0.38	0.75	
Nep	0.27		0.43			0.30			0.61
Kalsilite			0.09			0.04			0.07
Leucite	0.31								
Cor									
Di	13.39	4.71		0.65	3.82		0.65	3.89	
Hy		17.86		1.29	1.41		1.14	1.15	
Ol	**74.15**	73.43	95.40	93.51	92.35	95.76	93.65	92.31	22.96
Larnite	**10.87**		2.01			0.07			28.59
Acmite	0.23								
Ilm	0.13	0.13	0.13	0.25		0.62	0.25	0.12	2.41
Mt	0.65	0.54	0.74	1.06	0.93	1.27	1.06	0.92	1.22
Diff.I.	0.6	3.3	3.3	3.2	1.5	2.3	3.2	1.6	44.8
Elt	1361	1300	1774	1384	1370	1421	1385	1371	1495
EH_2Oc	0.11	0.17	-1.42	0.10	0.11	0.10	0.10	0.11	0.11

Note. The data Yu.I. Rylova, 1967.

Methods of research. The pore-forming and accessory minerals of picrites and picritic diabases were studied by us with the Tescan Vega II scanning electron microscope with the INCA PentaFetx3 energy dispersive spectrometer (KarGTU, Karaganda) and the INCA ENERGY energy dispersive spectrometer, OXFORD INSTRUMENTS, England (Lomonosov Institute of Geological Sciences, KISatpaeva, Almaty), installed on the electron probe microprobe Superprobe 733 (Japan).

The obtained information on the mineralogical composition of picrites made it possible to compare them with those of other picrite-containing complexes in the world.

Rock constituent and accessory minerals of picrites. **Olivine** is one of the main sources of information on the composition of the initial melt, which is fixed in the olivine. Olivine (Table 2) is characterized by a high level of Fe_2O_3 concentrations (14.32-17.92%) and NiO (0.31-0.42%), concentrations of

TiO_2, Al_2O_3, Cr_2O_3 are below the limit of their detection using this method. Forsterite minil of olivine picrites reaches 86 mol. %.

Clinopyroxene (table 2.1),does not contain TiO_2, Cr_2O_3, and is substantially undersaturated with Al_2O_3 (0.30%), but supersaturated with F_2O_3 (9.43%).

Hornblende in terms of chemical composition is close to the stoichiometric formula of ferro-pargasite (table 2.1) with a weak enrichment of sodium and potassium, especially the composition of chlorine.

Biotite, judging by the chemical composition (table 2.1), can be divided into magnesian low TiO_2 biotite and high TiO_2 phlogopite, the concentration of Al_2O_3 and MgO naturally decreases in the latter, but the role of K_2O significantly increases.

Manganoilmenite (table 2.2) is one of the main accessory minerals of picrates, with respect to the theoretical formula of ilmenite $FeTiO_3$, where iron accounts for 36.8% and oxygen and titanium for 31.6%, Ti (23.87%), but enriched Fe (38.29%), Mn (1.74%), Mg (0.86%), Ni (0.20%), V (0.45%). Relatively ilmenite, it is substantially supersaturated with V_2O_5 (1.38%), which determines the geochemical specialization of manganoilmenite from the picrites of the Karaturgai complex.

Titanium hematite is represented by lamellas, the amount of which reaches 80-90% of the total volume of manganoilmenite grains. The composition of the lamellas studied, like the matrix, is extremely unstable (table 2.2).

Chrompinelle is represented by idiomorphic grains and sharply xenomorphic grains performing irregular intervals between the idiomorphic grains of olivine and pyroxene. It is often possible to observe how the chrome-spinel penetrates the fissures into silicate minerals. Chromospinel crystals have a pronounced zoning in the distribution of Fe, Ti and Cr, Al, Mg. The grain rim is characterized by elevated Fe and Ti contents against the background of a sharp depletion of Cr and a relatively small decrease in Al, Mg concentrations (table 2.3).

According to the classification of N.V. Pavlova [26], chrome spinel corresponds to subferrialumochromite (Cr_2O_3 = 41.72-45.80%, Al_2O_3 = 16.63-16.67%), less often ferriallyumochromite (Cr_2O_3 = = 38.65%, Al_2O_3 = 11.60%) and they have a low and relatively constant chromicity (Cr/(Cr+Al) = 0.66-0.69), but their magnesia (Mg # = 0.06-0.44) varies over relatively wide limits. Xenomorphic crystals of subferrialumochromite are enriched with V_2O_3 (0.20%) and ZnO (0.62%). Narrow rims encircling the chrome-spinels are represented by chromium-magnetite. The grains of subferrialumochromite are dissected by veins of magnetite.

Apatite (table 2.1) is close in chemical composition to the stoichiometric formula: Ca10 (PO4) 6 (OH, F, Cl) 2, where F (0.9%) prevails over Cl (0.1%), while P2O5 (44.32%) is somewhat supersaturated .

Porphyry and accessory minerals of picritic diabases. In picritic diabases, we were able to study only clinopyroxene, biotite, manganoilmenite, chrome spinel.

The clinopyroxene (table 2.1.7-13) of picritic diabases with respect to those of picrites contains Cr_2O_3 (<1.03%) and TiO_2 (<1.22%), is enriched with Al_2O_3 (<3.36%) and MgO (<17.38%), but unsaturated CaO (19.63%).

Biotite (table 2.1.14) is represented by high-TiO_2 (2.95%), -Al_2O_3 (17.26%) by its variety.

Manganoilmenite (table 2.2) in picritic diabases is more common than in picrites and mainly it forms crystals with structures of decomposition of solid solutions, where the lamellae are composed of titanomagnetite. Their size reaches 100 microns. With respect to the manganoilmenite of picrites, it does not contain MgO, and the maximum concentration of MnO is 3.30%. Rarely in its composition is present Cr_2O_3 (0.66%). The lamellas of titanomagnetite are also enriched in MnO (1.38%).

Titanium hematite (table 2.2) relative to manganoilmenite of picrites is enriched in Fe_2O_3 (<76.33%), but contains less TiO_2 (<24.30%) and MnO. (<1.47%).

Chrompinel (table 2.4) forms ideally faceted crystals, which often reach 120 microns in diameter and are represented by polyhedra and rounded discharge. According to the classification of N.V. Pavlova [26] chromospin corresponds to subferrialiumochromite (Cr_2O_3 = 39.45-45.28%, Al_2O_3 = 15.25-16.72%) and has a low and relatively constant chromicity (Cr / (Cr + Al) = 0.62-0.65), but its magnesia (Mg # = 0.09-0.48) changes in relatively wide side-altars. In its composition sporadically there are CaO, MnO, V_2O_3, ZnO. A grain of ferrialumochromite was also encountered (Cr_2O_3 = 38.07%). Rarely, chrome-spinel crystals are edged with a thin rim of titanomagnetite containing MnO (1.60%) and ZnO (0.55%), as a rule, their concentration level is higher than in chrome spinel.

Table 2 – The composition of olivine picrites (wt.%)

#	1	2	3	4	5	6	7	8
Mın.	ol	ol	ol	ol	ol	ol	ol	ol
SiO_2	38.96	37.97	37.68	38.25	37.96	38.51	39.39	38.32
TiO_2								
Al_2O_3								
FeO	14.32	17.88	17.92	15.71	16.19	17.33	16.88	16.70
MnO		0.23	0.25	0.29	0.16			
MgO	46.07	43.27	43.48	45.06	45.0	44.58	44.63	43.52
CaO	0.25	0.34	0.30	0.27	0.28	0.19	0.36	0.30
NiO	0.39	0.31	0.37	0.42	0.32			
V_2O_5								
Ni(г/т)	3065	2436	2908	3300	2515			
Cl								
Summ	100.0	100.0	100.0	100.0	100.0	100.60	101.27	98.84
Formulas in terms of 4 (oxygen)								
Si	0.988	0.984	0.978	0.980	0.976	0.975	0.990	0.986
Fe+2	0.273	0.349	0.350	0.303	0.313	0.367	0.354	0.359
Mn		0.006	0.005	0.006	0.003			
Mg	1.742	1.672	1.682	1.722	1.725	1.683	1.667	1.669
Ca	0.007	0.009	0.008	0.007	0.008	0.005	0.01	0.008
Ni	0.008	0.006	0.008	0.009	0.007			
Fo	86.4	82.5	82.5	84.8	84.5	82.10	82.50	82.29
Fa	13.6	17.2	17.2	14.9	15.3	17.90	17.50	17.71
Tp		0.3	0.3	0.3	0.2	0.00	0.00	0.00
Lig.Comp.	0.523	0.695	0.694	0.587	0.605	0.727	0.707	0.717

Table 2.1 – The composition of rock-forming and accessory minerals (wt.%) Of picrites (1-6) and picritic diabases (7-17)

#	1	2	3	4	5	6	7	8	9
Mın	am	Cpx	bt	Flo	pl	ap	Cpx	Cpx	Cpx
SiO_2	43.86	53.36	36.22	39.97	41.67	0.73	51.34	51.64	51.48
TiO_2			0.42	3.58			0.93	0.86	1.28
Al_2O_3	13.16	0.30	19.84	13.49	28.89		3.37	3.06	3.05
FeO	20.07	8.58	8.99	9.80	6.55	1.03	6.91	7.18	9.51
MnO		0.44			0.39				
MgO	8.72	14.76	32.14	24.49	0.20		16.83	16.29	16.47
CaO	10.86	22.13	0.09	0.10	22.30	50.78	19.74	19.92	18.21
Na_2O	2.78	0.43							
K_2O	0.34		2.30	8.57					
P_2O_5						44.32			
Cr_2O_3							0.88	1.04	
V_2O_5									
SO_3						1.26			
Cl	0.21					0.22			
F						1.66			
Si	6.495	1.989	4.825	5.515	8.147	0.119	1.887	1.903	1.903
Aliv	1.505	0.011	3.115	2.194	6.652	0.0	0.111	0.097	0.097
∑		2					2	2	2
Alvi	0.792	0.003	0.00	0.00		0.00	0.035	0.036	0.036
Ti			0.042	0.372	0,00	0.00	0.026	0.024	0.036
Fe(iii)	0.00	0.058	0.0	0.0			0.000	0.000	0.000
Fe(ii)	2.485	0.208	1.001	1.131	1.070	0.140	0.213	0.222	0.294
Mn		0.014	0.00	0.00		0.00	0.00	0.00	0.00
Mg	1.925	0.820	6.383	5.037		0.00	0.923	0.985	0.908
Ca	1.723	0.884	0.013	0.015	4.668	8.870	0.778	0.786	0.721
Na	0.798	0.031	0.000	0.000		0.00	0.00	0.00	0.00
K	0.064		0.391	1.508		0.00	0.00	0.00	0.00
P						6.117			
Cl						0.061			
F						0.856			
OH						0.083			
Mg*	0.44	0.80					0.81	0.80	0.76
Wo		44.54					40.66	41.32	37.50
En		41.34					48.24	47.03	47.2
Fs		14.11					11.11	11.65	15.31
Note. Amphibole-ferro-pargasite. Flo – phlogopite.									

Table 2.1 (continuation 1)

#	10	11	12	13	14	15	16	17
Mın	Cpx	Cpx	Cpx	Cpx	Cpx	Cpx	Cpx	Bt?
SiO_2	57.87	54.50	57.48	56.07	51.73	51.50	51.59	35.68
TiO_2	0.0	0.37	0.0	0.0	0.65	0.70	0.97	2.95
Al_2O_3	0.85	2.30	1.11	2.69	2,42	3.03	2.66	17.26
FeO	9.17	15.75	9.36	12.69	7.91	7.18	8.37	16.72
MnO					0.43	0.22	0.22	
MgO	18.86	15.19	18.38	15.89	17.61	17.22	17.00	24.83
CaO	13.25	11.33	13.20	12.34	18.65	19.34	18.62	0.0
Na_2O	0.0	0.56			0.22	0.50	0.32	0.0
K_2O				0.32				2.56
Cr_2O_3			0.47		0,60	0,51	0,41	
Сумма	100.0	100.0	100.0	100.0	100.21	100.20	100.17	100.0
Si	2.076	2.017	2.067	2.044	1.906	1.895	1.904	4.939
Aliv	-0.076	-0.017	-0.067	-0.044	0.094	0.105	0.096	2.816
∑	2	2	2	2	2	2	2	
Alvi	0.112	0.117	0.114	0.159	0.011	0.026	0.019	0.000
Ti	0.000	0.010	0.000	0.000	0.018	0.019	0.027	0.307
Fe(iii)	0.000	0.000	0.000	0.000	0.068	0.091	0.051	
Fe(ii)	0.282	0.495	0.288	0.396	0.175	0.128	0.206	1.935
Mn	0.000	0.000	0.000	0.000	0.013	0,007	0.007	0.000
Mg	1.009	0.838	0.985	0.863	0.967	0.945	0.935	5.124
Ca	0.509	0.449	0.509	0.482	0.736	0.762	0.736	0.000
Na	0.000	0.00	0.000		0.016	0.036	0.03	0.000
K				0.015				0.452
Mg*	0.79	0.63	0.78	0.69	0.80	0.81	0.78	
Wo	28.30	25.21	28.53	27.67	37.57	39.44	38.03	
En	56.05	47.04	55.28	49.58	49.37	48.87	48.32	
Fs	15.65	27.75	16.18	22.74	13.05	11.70	13.64	

Table 2.2 – Phase compositions of the decomposition structure of manganoilmenite solid solutions (mass%) of picrites (1-11) and manganoilmenite and titanogenite of picritic diabases (12-25) of the Karaturgai complex

#	Mıneral	TiO_2	FeOt	MnO	MgO	Cr_2O_3	CaO	V_2O_5
1	2	3	4	5	6	7	8	9
	Ламели – матрикс							
1	Titanium hematite	30.40	66.04	1.46	0.32	0.52	0.13	1.14
2	Ilmenite	38.23	57.82	1.95	0.61	0.40	0.15	0.85
3	Ilmenite	46.58	49.15	2.90	0.75	0.05	0.16	0.41
4	Ilmenite	50.43	44.89	3.09	0.85	0.10	0.27	0.36
5	Ilmenite	46.09	49.35	2.81	0.84	0.27	0.23	0.42
6	Ilmenite	36.95	59.21	1.91	0.60	0.35	0.19	0.79
7	Titanium hematite	33.51	62.80	1.71	0.37	0.34	0.08	1.19
8	Ilmenite	46.27	49.36	2.53	1.08	0.03	0.08	0.65
9	Titanium hematite	33.95	61.39	2.00	0.31	0.37	0.16	0.83
10	Ilmenite	52.03	43.86	3.14	0.51	0.06	0.13	0.27
11	Ilmenite	52.82	43.45	2.91	0.25	0.27	0.10	0.20
	Ламели							
12	Titanium hematite	22.23	76.33	1.44				
13	Titanium hematite	24.30	73.57	1.47				0.66
	Матрикс							
14	Manganoilmenite	51.62	44.25	3.44			0.69	
15	Manganoilmenite	51.45	45.32	3.23				
16	Manganoilmenite	52.44	44.41	3.15				
17	Manganoilmenite	52.27	44.47	3.26				
18	Manganoilmenite	52.68	44.43	2.89				
19	Manganoilmenite	51.98	44.03	3.39				0.60
20	Manganoilmenite	51.54	45.19	3.27				
21	Manganoilmenite	52.70	44.19	3.11				
22	Manganoilmenite	52.50	44.07	3.43				
23	Manganoilmenite	52.65	44.02	3.33				
24	Manganoilmenite	52.38	44.49	3.13				
25	Manganoilmenite	52.74	43.95	3.31				

Table 2.3 – Composition of chrome-spinel (wt.%) Picrite of the Karaturgai complex

#	1	2	3	4	5	6	7	8	9	10
TiO_2	1.43	1.51	1.37	1.60	1.27	1.10	1.18	1.37	1.32	1.32
Al_2O_3	15.26	15.48	15.63	14.73	14.34	14.12	13.50	14.00	13.20	13.87
FeO	25.76	26.49	25.45	26.83	30.47	30.83	33.28	33.46	38.12	35.90
MnO										0.92
MgO	11.30	10.95	11.08	11.22	8.28	7.56	6.58	7.01	4.70	4.27
Cr_2O_3	46.25	45.57	46.46	45.63	45.64	46.39	45.46	44.16	42.66	43.72
Summ	100	100	100	100	100	100	100	100	100	100
Fe_2O_3	7.94	8.035	7.233	8.894	8.247	7.742	8.805	9.448	10.86	8.615
FeO	18.62	19.260	18.942	18.827	22.959	23.864	25.357	24.96	28.34	28.148
24-anion										
Ti	0.275	0.290	0.263	0.308	0.250	0.218	0.236	0.272	0.267	0.268
Al	4.591	4.664	4.704	4.442	4.420	4.379	4.225	4.358	4.188	4.405
Fe3+	1.525	1.546	1.390	1.712	1.643	1.533	1.759	1.878	2.199	1747
Fe2+	3.974	4.117	4.045	4.028	5.021	5.252	5.631	5.512	6.381	6.342
Mn										
Mg	4.301	4.173	4.218	4.28	3.229	2.966	2.605	2.76	1.886	1.715
Ca										
Cr	9.335	9.211	9.380	9.230	9.437	9.652	9,544	9.221	9.079	9.314
Cr#	0.67	0.66	0.67	0.68	0.68	0.69	0.69	0.68	0.68	0.68
Fe#	0.56	0.58	0.56	0.57	0.67	0.70	0.74	0.73	0.82	0.83
Mg#	0.44	0.42	0.44	0.43	0.33	0.30	0.26	0.27	0.18	0.17
Fe2*	3.974	4.117	4.045	4.028	5.022	5.252	5.631	5.512	6.381	6.342
Fe3*	1.525	1.545	1.390	1.712	1.642	1.533	1.759	1.877	2.199	1.747

Table 2.3 (continuation 1)

#	11	12	13	14	15	16	17	18	19	20
TiO_2	1.50	1.20	1.19	6.99	2.88	1.69	1.13	1.33	1.05	1.18
Al_2O_3	11.74	13.79	13.68	6.37	10.26	16.82	14.19	7.48	8.00	7.77
FeO	44.80	39.08	41.06	61.70	49.96	35.27	37.66	72.33	71.74	71.73
MnO				1.12						0.54
MgO	2.82	2.21	1.48		0.86	7.81	5.79	0.87	0.84	1.03
Cr_2O_3	39,13	42.85	41.76	23.16	33.85	38.41	41.23	15.82	16.32	15.90
V_2O_3			0.20	0.66	0.46			0.82	0.82	0.65
ZnO		0.88	0.62		1.74			1.36	1.25	1.19
Fe_2O_3	15.083	8.726	9.356	25.564	18.074	11.96	12.195	42.12	43.49	44.25
FeO	31.228	31.288	32.641	38.696	33.696	24.51	26.687	31.15	32.60	31.91
24										
Ti	0.309	0.247	0.246	1.500	0.606	0.329	0.226	0.280	0.221	0.248
Al	3.792	4.445	4.438	2.141	3.385	5.138	4.445	2.467	2.633	2.556
Fe3+	3.111	1.796	1.938	5,486	3.807	2.333	2.439	9.289	9.139	9.295
Fe2+	7.157	7.142	7.513	9.229	7.888	5.312	5.932	7.636	7.613	7.446
Mn				0.271						0.158
Mg	1.152	0.901	0.607		0.359	3.018	2.294	0.363	0.350	0.427
Ca										
Cr	8.479	9.265	9.087	5.222	7.492	7.871	8.664	3.500	3.603	3.508
Zn			0.126	0	0.360			0.281	0.258	0.245
V			0.44	0.151	0.103			0.184	0.184	0.145
Cr#	0.69	0.68	0.67	0.71	0.69	0.61	0.66	0.59	0.58	0.58
Fe#	0.90	0.91	0.94	1.00	0.97	0.72	0.78	0.98	0.98	0.98
Mg#	0.10	0.09	0.06		0.03	0.28	0.22	0.02	0.02	0.02
Fe2*	7.157	7.142	7.513	9.229	7.888	5.312	5.932	7.636	7.613	7.446
Fe3*	3.111	1.800	1.938	5.486	3.810	2.333	2.439	9,290	9.139	9.295

Table 2.3 (continuation 2)

#	21	22	23	24	25	26	27	28	29	30
TiO_2	1.75	1.27	1.36	2.50	2.22	2.03	2.12	2.04	1.03	1.62
Al_2O_3	14.27	15.04	14.70	17.65	17.24	16.56	16.60	17.17	5.29	1.69
FeO	44.10	32.76	34.51	30.84	36.39	37.74	34.15	31.39	71.69	73.89
MnO						0.17			0.71	0.91
MgO	2.49	8.16	6.22	10.55	6.67	4.85	7.64	8.70	0.73	
Cr_2O_3	36.89	42.20	43.21	38.46	37.49	37.77	39.48	40.69	19.88	20.70
V_2O_3	0.50	0.57							0.68	0.57
ZnO						0.87				0.62
Fe_2O_3	13.081	10.522	9.163	10.767	10.681	10.484	10.073	8.814	43.27	45.337
FeO	32.890	23.292	26.265	21.151	26.779	28.306	25.086	23.459	32.753	33.093
Ti	0.358	0.249	0.271	0.447	0.436	0.405	0.415	0.395	0.219	0.352
Al	4.572	4.621	4.587	5.277	5.300	5.177	5.086	8.288	1.732	0.576
Fe3+	2.676	2.064	1.826	2.055	2.097	2.092	1.970	1.709	9.203	9.859
Fe2+	7.349	5.078	5.815	4.487	5.842	6.278	5.453	5.054	7.741	7.997
Mn						0.038			0.170	0.223
Mg	1.009	3.172	2.455	3.990	2.594	1.918	2.961	3.342	0.308	
Ca										
Cr	7.928	8.698	9.046	7.714	7.732	7.921	8.114	8.288	4.443	4.729
Zn						0.170				0.132
V	0.109	0.119							0.154	0.132
Cr#	0.63	0.65	0.66	0.59	0.59	0.60	0.61	0.61	0.72	0.89
Fe#	0.91	0.69	0.76	0.62	0.75	0.81	0.71	0.67	0.98	1.00
Mg#	0.09	0.35	0.24	0.37	0.25	0.19	0.29	0.33	0.02	0.0
Fe2*	7.349	5.078	5.815	4.487	5.842	6.278	5.453	5.054	7.741	7.997
Fe3*	2.676	2.064	1.825	2.055	2.096	2.092	1.970	1.708	9.203	9.859

Table 2.4 – Composition of chrome spinels (wt.%) Of picritic diabases of the Karaturgai complex

#	1	2	3	4	5	6	7	8	9	10	11	12
TiO_2	1.30	1.46	1.43	1.50	1.44	1.42	1.61	1.52	1.28	1.48	1.29	16.06
Al_2O_3	15.89	15.38	15.25	16.44	16.40	15.25	16.59	15.68	15.82	16.72	16.22	
FeO	39.80	36.25	33.18	32.17	36.78	33.18	29.24	34.18	30.25	23.98	33.59	71.30
MnO	0.66		0.82		0.90	0.83						1.73
MgO	2.26	8.83	6.36	8.00	4.20	6.36	9.68	6.27	8.65	12.54	5.41	
CaO								0.29	0.21			
Cr_2O_3	39.45	38.07	42.96	41.37	39.60	42.96	42.69	42.06	43.62	45.28	43.49	10.32
V_2O_3	0.31			0.52			0.19		0.17			
ZnO	0.33				0.68							0.59
Fe_2O_3	9,23	15.21	8.69	9.15	9.57	8.71	8.62	8.94	8.73	7.77	6.61	29.49
FeO	31.49	22.56	25.37	23.94	28.57	25.35	21.48	26.14	22.39	16.99	27.64	44.77
Ti	0.265	0.284	0.284	0.293	0.289	0.282	0.311	0.301	0.249	0.280	0.257	3.546
Al	5.073	4.688	4.743	5.029	5.154	4.743	5.016	4.868	4.830	4.959	5.063	0.000
Fe3+	1.882	2.960	1.725	1.786	1.920	1.729	1.665	1.771	1.702	1.471	1.318	6.516
Fe2+	7.135	4.879	5.598	5.197	6.282	5.594	4.608	5.757	4.850	3.575	6.121	10.99
Mn	0.151	0.00	0.183	0.000	0.203	0.186	0.000	0.000	0.00	0.000	0.000	0.430
Mg	0.913	3.405	2.503	3.096	1.67	2.502	3.702	2.462	3.341	4.705	2.136	0.000
Ca	0,000	0.00	0.00	0.00	0.00	0.00	0.000	0.082	0.058	0.000	0.000	0.000
Cr	8.450	7.784	8.964	8.490	8.349	8.964	8.659	8.759	8.934	9.009	9.106	2.395
Zn	0.066	0.00	0.00	0.000	0.134	0.000	0.000	0.000	0.000	0.000	0.000	0.128
V	0.065	0.00	0.00	0.108	0.000	0.000	0.039	0.000	0.035	0.000	0.000	0.000
Cr#	0.62	0.62	0.65	0.63	0.62	0.65	0.63	0.64	0.65	0.64	0.64	
Fe#	0.91	0.70	0.75	0.69	0.83	0.75	0.63	0.75	0.66	0.52	0.78	
Mg#	0.09	0.30	0.25	0.31	0.17	0.25	0.27	0.25	0.34	0.48	0.22	
Fe2*	0.791	0.622	0.764	0.744	0.766	0.764	0.735	0.765	0.740	0.708	0.823	0.628
Fe3*	0.209	0.378	0.236	0.256	0.234	0.236	0.265	0.235	0.260	0.292	0.177	0.372
Note. The amounts of FeO and Fe2O3 are calculated by stoichiometry.												

Discussion. Species karaturgayskogo hypabyssal diabase picritic complex are derivatives melting spinel lherzolite whereas rock harzburgite-peridotite-gabbro plagiogranite complexes suprasubduction ofiolitov Central Kazakhstan formed by melting garnet lherzolite (see figure 3, B). The cumulative peridotites of the suprasubduction ophiolites of Central Kazakhstan are depleted of Al_2O_3 (see figure 3, D) relative to the picrits of the Karaturgai complex. If we turn to the TiO_2·10-Al_2O_3-MgO diagram [see figure 2, A], then these complexes also correspond to two different series: the first - picritic, and the latter - komatiite and partly boninitic. These differences are also evident in the Al_2O_3/TiO_2–CaO/Al_2O_3 diagram (see figure 2, B).

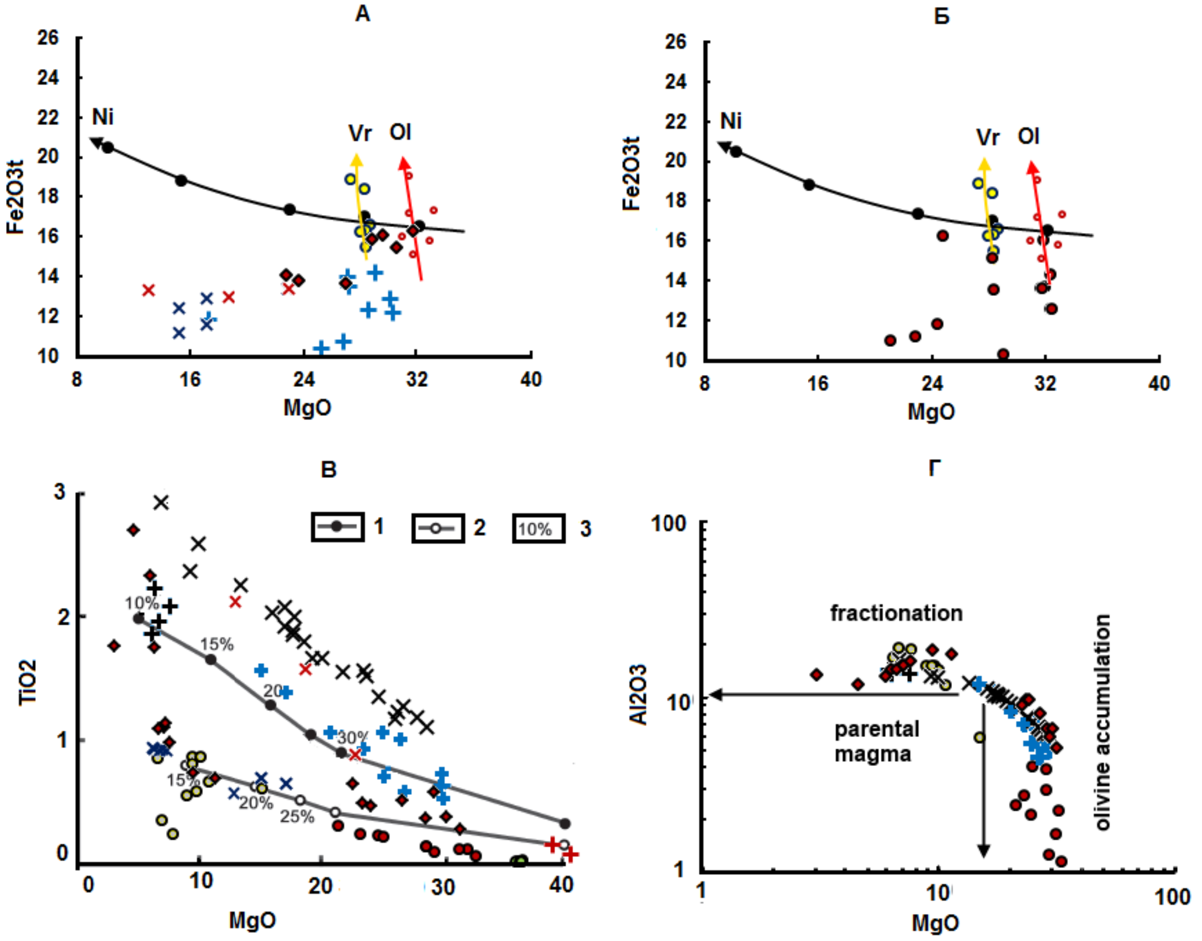

Figure 3 –
A, B – The diagram of MgO-Fe2O3t, wt. %.
Arrows show trends: Ni - rocks Pechenga nickel complex; non-metallic rocks Pechenga:
Vr - serpentinized verlites and Ol-serpentinized olivinites.
B – Diagram TiO_2-MgO, wt. % [19],
G – Diagram of Al_2O_3-MgO, wt. % [27].
1 - trend melting of spinel peridotite; 2 - trend melting garnet peridotite; 3 - degree of melting.
For legendary symbols, see figure 2.

Among the magnesian complexes of the Noril'sk region [23], only the rocks of the Gudchikhin suite, which correspond to the picrites of the Hawaiian plume, correspond to the levels of TiO2 (figure 3, B), to picrites. correspond to the derivatives of melting of spinel lherzolite. Whereas the rocks of the Tukon, Nadezhda suite and the Maslovskaya intrusion of the Norilsk trap are the derivatives of the melting of the garnet peridotite and, therefore, do not find analogy with the picrites of the Karaturgai complex.

The picrits of the Karaturgai complex relative to those of the Hawaiian plume [22, 27] are depleted of TiO2, but somewhat more magnesian, which reflects their high degree of melting (see figure 3, B). They also have less alumina than in picrites of the Hawaiian plume (see figure 3, D).

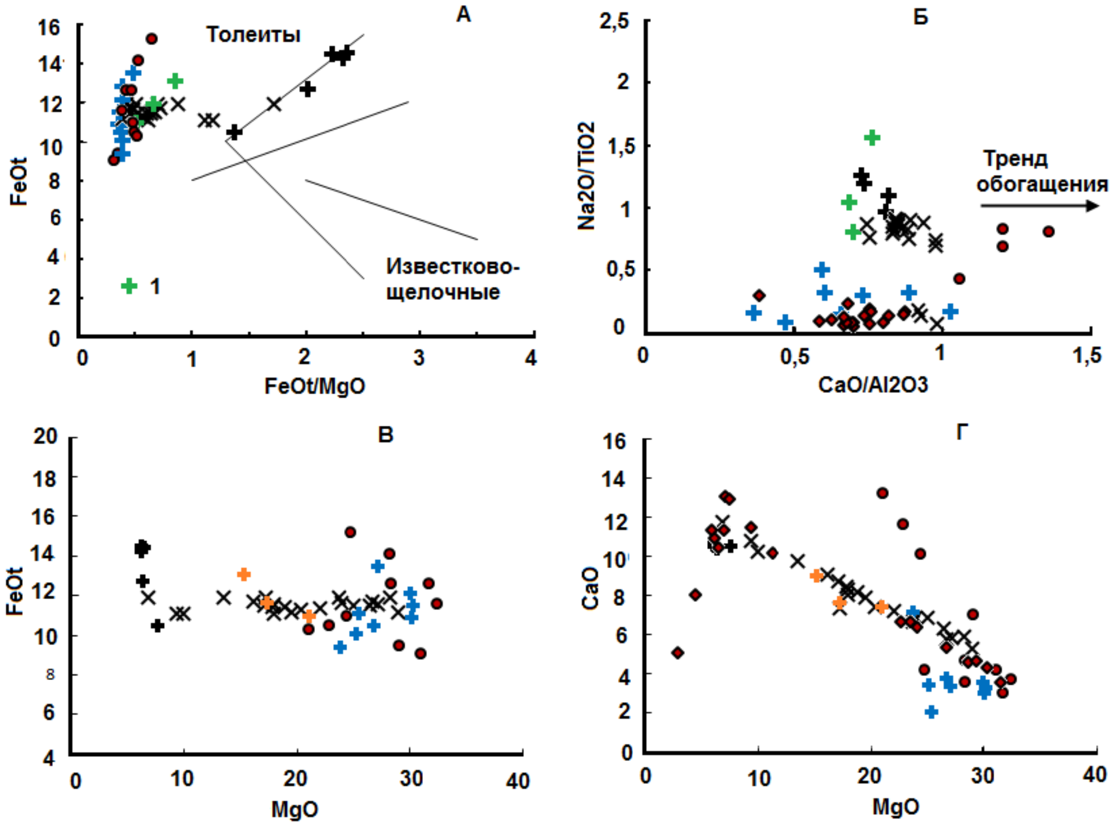

Figure 4 –
A – Diagram of FeOt-FeOt / MgO, wt.% [28],
B – Diagram of Na2O / TiO2-CaO / Al2O3, wt. % [29],
B – The FeOt-MgO diagram, wt. % and
G – Diagram of CaO-MgO, wt. %.
1 – picritic diabases of the Karaturgai complex.
See Figure 2 for legendary symbols.

The picrits of the Karaturgai complex are characterized by a constant growth of FeOt with a weak fluctuation of the FeOt / MgO ratio (see figure 4) and minor MgO oscillations, while in the Hawaii plume picrites the level of FeOt concentration remains practically constant, but the level of MgO content significantly changes (see figure 4, AT). From the latter, picrites also differ in the ratios of Na_2O/TiO_2-CaO/Al_2O_3, but it should be noted that the diabase and picrite diabase of the Karaturgai complex are fairly close in CaO/Al_2O_3 ratio, with some depletion of Na_2O.

Particular attention should be paid to the nature of the distribution of CaO relative to MgO (see figure 4, D). Diabases and picritic diabases of the Karaturgai complex lie on the trend of picrites of the Hawaiian plume, while the actual picrites deviate from this trend, which can be caused by intra-chamber crystallization and the accumulation of olivine cumulates.

Pore-forming olivines from picrites of the Karaturgai complex on the Fo NiO, -MnO diagrams (figure 5, A, B, respectively) are located in the olivine field of intraplate magmatic complexes, as well as olivine from picrites of the Hawaiian plume. This figure clearly shows that the figurative points of the olivine picrites of the Karaturgai complex are significantly removed from the MORB and trap fields of the Norilsk region, and they have a completely different enrichment trend of NiO and MnO. With respect to the olivine picrites of the Hawaiian plume, whose magmas originate at a depth of at least 660 km, they are enriched in iron and contain somewhat less NiO, but are enriched in MnO.

All this indicates the geochemical specialization of the Karaturgai complex inherent in the picrites, accompanied by Cu-Ni + Zn-Pb + PGM mineralization, the formation of which was associated with the melting of the depleted mantle source Ti and Cr but enriched with elements of the iron group, as well as a number of rare-earth elements (La, Yb) and lithophilic elements (Y, Zr, Sr, Ba).

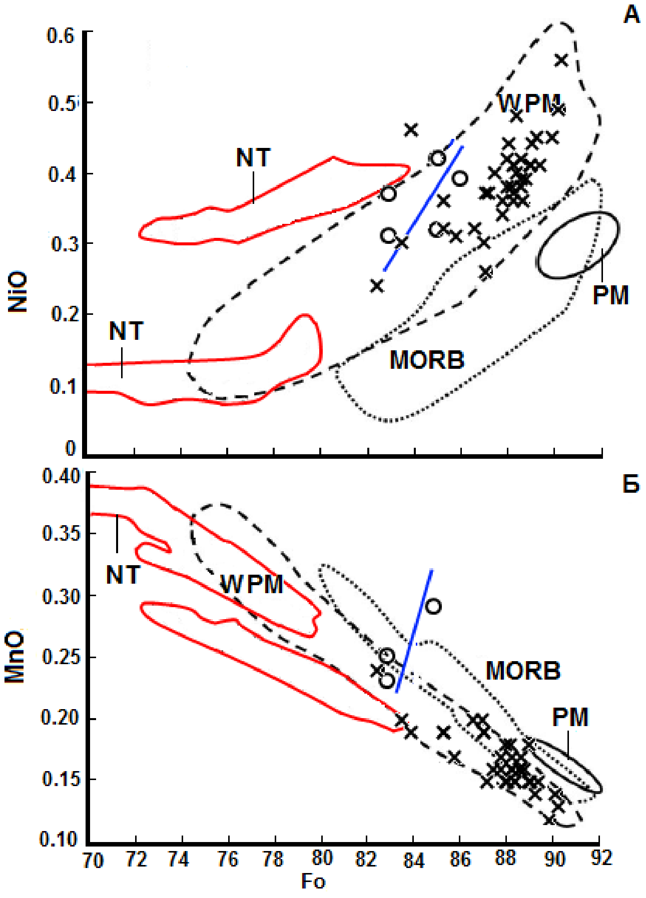

Figure 5 – Diagrams A – Fo (mol%) - NiO (wt%), B – MnO (wt%) for olivines from picrites of the Karaturgai complex.
PM - olivine field in equilibrium with peridotite material; MORB - field of phenocrysts from basalts of mid-oceanic ridges; WPM - the field of phenocrysts of olivine from intraplate magmatic reservoirs formed under a powerful (more than 70 km) lithosphere [30]; NT - olivine from the trap of the Norilsk region [30]; olivine from picrites of the Hawaiian plume [22].

It should be especially noted that the rock-forming olivines and clinopyroxenes of the picrite of the Karaturgai complex do not contain Cr_2O_3, TiO_2, which indicates a high depletion degree of the initial mantle material enriched in Ni and Cu sulphides.

While clinopyroxenes of picritic diabases are on the contrary enriched with Cr_2O_3 and TiO_2, and the rock itself contains a high-titanium chrome spinel. Such differences in the chemical composition of the rock-forming and accessory minerals of picrites and picritic diabases have several explanations. Picritic diabases can be considered as a hardening zone in which the (original) primary composition of the mantle substance is preserved, and picrites as the final product of its melting. It is not excluded that they belong to two different mantle sources.

The presence in the picritic diabases of the roof of the streams together in one sample of the crystals of chrome spinel, manganoylmenite and titanogenate gives grounds to speak of their crystallization under hypabyssal conditions. Since iron is in a high degree of oxidation in titanogemate, this suggests its formation under conditions with a higher oxygen potential.

The chemical composition of the picrites of the Karaturgai complex testifies to their belonging to the ultrabasites of the normal range, which was noted earlier by NP. Mikhailov and Yu.L. Semenov [5], with the ratio $CaO/Al_2O_3<1$, the content of TiO_2 (<1%), with a constant but insignificant predominance of Na_2O (<0.65%) over K_2O (<0.24%). Associates with high-Fe picrites, tholeiitic diabases also have low CaO/Al_2O_3 ratios, significantly below 1, but with an elevated TiO_2 content> 1% and a constant predominance of Na_2O (> 2.0%) over K_2O (> 0.25%).

The absence of the lavas, volcanic breccias, hyaloclastites, and tuffs of picrites, which are so characteristic of the intensive stretching of the continental crust in the Western Ulytau belt, 19 attests to the formation of the hypabyssal rocks of the diabase-picritic complex under the conditions of the general compression (collision) regime in the late stages of development Ulytau folded area in the Neoproterozoic during the formation of the Rodinia supercontinent.

Manifestations of picrite magmatism in such areas are due to an increase in the "stiffness" of folded regions and the establishment of deep inner crustal faults [19].

Probably, under such conditions, magmatism proceeded within the Western Ulytau belt. The association of picritic and diabase magmatism to deep faults, fixed in the Mohorovicic interface within the described region, was discussed earlier by GF Lyapichev [9].

Based on the spatial relationship of picrites with carbonatitoids, one can consider picrites and apopycritic olivinites as convergent rocks.

According to the character of accumulation of the main major components (figure 6) tholeitic picrites have analogy with non-diamond and poor diamondiferous kympicrites.

However, the studied olivine of tholeiitic picrites contains more iron (Fo 85-90%) and it is enriched with Ni (<0.33%) and MnO (<0.29%). Phlogopite picrites enriched TiO_2 (3.58%) and does not contain MnO, and ilmenite enriched MgO (<1.08%), MnO (3.14%), CaO (0.27%), V_2O_3 (0.85%) and Cr2O3 (<0.40%), which is uncharacteristic both for kimpicrites and alpicrites, and even more so for diamondiferous kimberlites [31].

According to the mineralogical and petrochemical composition (figure 6) picritic diabase approaching rocks alpikritovoy group, but their enriched ilmenite MnO (<3.44%), and MgO and Cr_2O_3 absent. The present composition picritic diabase chromospinel (Cr_2O_3 <45.28%, MgO <8.83%), not occurring in the composition of titanium-alpicrıtes [31].

Apopycritic olivinites of the Karaturgai complex are often brecciated, carbonized and are larnite-normative.

In the diagrams (figure 6) their figurative points are located in the field of diamondıferous kimberlite compounds. However, it should be remembered that larnite is found not only in peridotites, but also in ankaratrite and alnite. The latter are the extreme members of the alpicritic group. Recently found [32] that comagmatic alneites and kimberlites similarity carbonated kimberlites and carbonatites is a consequence of the evolution of the mantle magma. The presence of apatite, hornblende and phlogopite composed apopycritic olivinites as in picrites themselves, suggesting their comagmatic with kimberlite or alnoeitis. This understanding of the genesis of picrites is in complete agreement with their association with carbonatitoids, which are sources of rare earths.

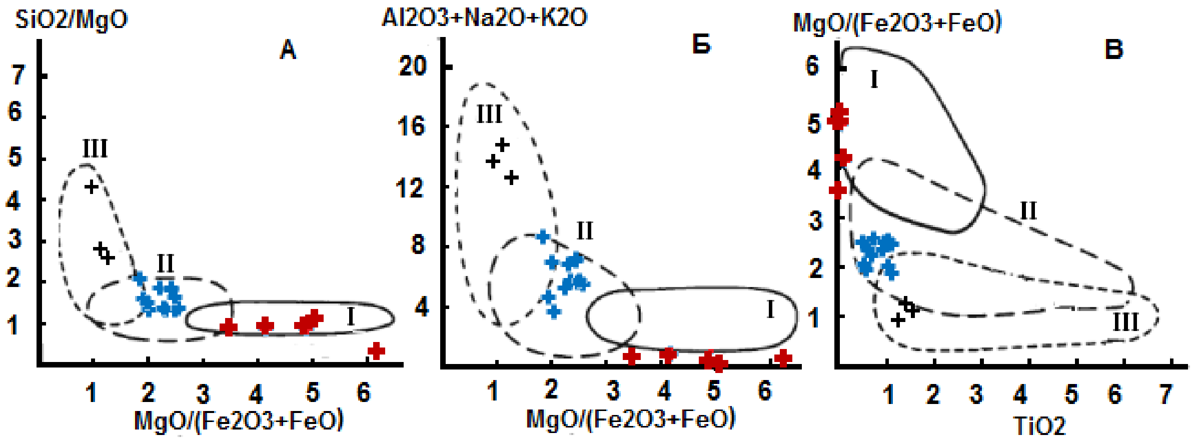

Figure 6 – Diagrams of SiO_2/MgO–MgO/Fe_2O_3t (A), (Al_2O_3 + Na_2O + K_2O)–MgO/Fe_2O_3t (B) and MgO/Fe_2O_3t–TiO_2 (B) for apopycritic serpentinites (red cross), picrites (blue cross) and picritic diabases (black cross) of the Karaturgai complex.

I - the region of the compositions of diamondiferous kimberlites; II - the region of the compositions of non-diamondıferous and poor diamondıferous kimicrites; III - area of compositions of alpicrites [31].

Petrogeneric conclusions. The accomplished petrogeochemical comparison of the rocks of the Karaturgai complex allows us to make a number of preliminary conclusions about the genesis of basic and ultrabasic magmas and their metallogeny within the Western Ulytau belt.

The rocks of the Karuturgai complex of the Western Ulytau belt formed at a high degree of melting of the spinel lherzolite than they differ from the harzburgite-peridotite-gabbro-plagiogranite complexes of ophiolites of Central Kazakhstan, formed as a result of melting of the garnet peridotite.

Based on the Fe_2O_3/FeO ratio [33], the first type picrites crystallized at a high oxygen content, while the second type picrites, picritic diabases and diabases crystallized with a smaller oxygen content in the magmatic melt.

The rocks of the Karuturgai complex of the Western Ulytau belt were formed at a high degree (from 35% to 10%) of melting of spinel lherzolite. The high degree of melting of spinel lherzolite suggests that the rocks of the complex were formed during the intra-chamber differentiation of mantle picrite-carbonatite magma.

The sulphide platinum-copper-nickel-lead-zinc mineralization, rich in rare-earth elements, is genetically and spatially associated with the picrites of the Karaturgai complex. Such ore mineralization, as shown by recent studies [33], is formed in the process of enrichment of picritic magma with silica and alkalis upon the absorption of crustal material and addition of sulfur from an external source.

The genetic connection of picrites with carbonatitoids, ore loading and their petrochemical specialization does not exclude the possibility that carbonatitoids can be the main sources of diamonds, which are known today in the composition of carbonatites of folded belts [34]. The formation of carbonatitoids of the Karaturgai complex having yttrium specialization should apparently be linked to the transfer of carbon from the mantle source by reducing fluids consisting of methane, hydrogen, carbon monoxide and other gases [35] that contributed to the formation of carbonatitoids.

However, the presence in the picritic olivine structure of the extreme member of the picrite-diabase series of the normative larnite does not exclude its formation due to the differentiation of high-calcium larnite-normative melts, which may be similar in composition to kimberlites [36].

The introduction of the hypabyssal Karaturgai complex of the Western Ulytau belt occurred against the background of a collision of the folded structures of the Ulytau megaterrain during the formation of the Rodinia supercontinent [37], and not in the process of rifting the continental and the more so the oceanic crust.

The age of the rocks of the Karaturgai complex of the Western Ulytau belt is conditionally assumed to be Neoproterozoic to the riftogenic stage (825 Ma) [37].

This is confirmed by their structural position, as well as by the fact that they form dikes and sills not only within the Mesoproterozoic strata, but also from the Neoproterozoic Bozdak series and in the composition of younger complexes. Ulytau is not found.

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ПРОБЛЕМЫ ПЕТРОЛОГИИ УЛЬТРАОСНОВНЫХ ПОРОД БАССЕЙНА РЕКИ КАРАТУРГАЙ СЕВЕРНОГО УЛУТАУ (ЦЕНТРАЛЬНЫЙ КАЗАХСТАН)

«Только путем синтеза всех наук о Земле
мы можем отыскать "истину".»
Альфред Вегенер

Аннотация. В статье рассмотрены вопросы петрологии и металлогении основных и ультраосновных пород хребта Северный Улытау. В составе Западно-Улытауского пояса выделен гипабиссальный каратургайский диабаз-пикритовый комплекс, который является производным плавления шпинелевых перидотитов, что отличает его от нижнепалеозойских надсубдукционных офиолитовых комплексов Центрального Казахстана, являющихся продуктами плавления гранатовых лерцолитов. Даны составы породообразующих и акцессорных минералов пикритов и пикритовых диабазов. Показано, что апопикритовые оливиниты каратургайского комплекса являются ларнит-нормативными породами. Присутствие в составе апопикритового оливинита крайнего члена пикрит-диабазового ряда нормативного ларнита не исключает его образование вследствие дифференциации высококальциевых ларнит-нормативных расплавов, которые могут быть близки по составу к кимберлитам. Учитывая геохимическую специализацию пород каратургайского комплекса, высказано предположение, что их формирование связано с плавлением деплетированного мантийного источника Ti и Cr, но обогащенного Cu-Ni + Zn-Pb + МПГ, а также рядом РЗЭ (Y, La, Yb) и литофильных элементов (Zr, Sr, Ba). Внедрение гипабиссального каратургайского комплекса происходило на фоне коллизии складчатых структур Улытауского мегатеррейна в период образования суперконтинента Роди́ния.

Ключевые слова*:* Улытау, Казахстан, пикриты, диабазы, медно-никелевые руды, палладий, платина, неопротерозой.

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СОЛТҮСТІК ҰЛЫТАУДЫҢ ҚАРАТОРҒАЙ ӨЗЕНІ БАССЕЙІНІҢ УЛЬТРАНЕГІЗГІ ТАУ ЖЫНЫСТАР ПЕТРОЛОГИЯСЫНЫҢ ПРОБЛЕМАЛАРЫ (ОРТАЛЫҚ ҚАЗАҚСТАН)

Аннотация. Мақалада Солтүстік Ұлытау жотасының негізгі және ультранегізгі тау жыныстарының металлогения және петрология мәселелері қарастырылған. Батыс – Ұлытау белбеу құрамында гипабиссалды қараторғай диабаз-пикритті кешен бөлінген, ол шпинель перидотиттің балқуы нәтижесінде пайда болады, жәнеде ол гранат лерциолиттердің балқу өнімі болатын Орталық Қазақстанның төмен палеозой субдукция үстіндегі офиолитті кешенінен айырықша. Тау жынысын құрайтын және пикриттің және пикритті диабаз акцессорлық минералдар құрамы берілген. Қараторғай кешенінің апопикритті оливиниттері ларнит-нормативті тау жыныстары болып табылады. Апопикритті оливиниттің құрамында пикрит-диабаз қатарының шекті мүшесі нормативті ларниттің болуы, оның құрамы бойынша кимберлиттерге жақын болып, жоғары-кальцийлі ларнит-нормативті ерітінділердің дифференциациялануы салдарынан болуы мүмкін. Қараторғай кешені тау жыныстарының геохимиялық мамандандырылуын ескере отырып олардың пайда болуы Ti және Cr диплетталған мантий көздерінің балқуымен, бірақ Cu-Ni+ Zn-Pb +МПГ, жәнеде РЗЭ (Y, La, Yb) қатарымен және литофильді элементтердің (Zr, Sr, Ba)байытылуыменбайланысты пайда болғану туралы болжамдалған. Қараторғайдың гипабиссалды кешенінің еңгізілуі Родиния суперконтиненті пайда болуы кезінде Ұлытаудың мегатеррейінің қатпарлы құрылымдарының коллизиясы кезінде болды.

Түйін сөздер: Ұлытау, Қазақстан, пикриттер, диабаздар, мыс-никельді кеніштер, палладий, платина, неопротерозой.

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