IOP Conf. Series: Earth and Environmental Science **110** (2017) 012016 doi:10.1088/1755-1315/110/1/012016

Features of geology and composition of rocks from the alkaline-gabbroic University massif (N-E Kuznetsky Alatau ridge, Siberia)

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Abstract. This paper discusses specifics of petrography and structural tectonic position of the alkaline-gabbroic University massif, which is a sort of analogue of the Kiya-Shaltyr deposit of nepheline ores in this area that was very slightly eroded. In this work, we will also present new precise analytical data on rare and trace element distribution in major intrusive phases of this geological object, and also isotope dating on the basis of method Sm-Nd.

1. Introduction
The University Massif is one of the least studied objects in alkaline-gabbroic association on the Northern slope of Kuznetsk Alatau also known as Mariinsk taiga (local term for this area). It was discovered during prospecting works by geologists of Martaiga geological prospecting expedition operation and employees of Tomsk State University in 1981-1987. Up until now, some researchers think that this geological object does not exist (verbal message from leading geologist of “WestSibgeologsurvey” A.N. Uvarov). However, during magnetometric survey, above ground and drilling works in 1987 they were able to outline and obtain samples of holocrystalline rocks correlating to main intrusive phases of Kiya Shaltyr and other adjacent alkaline-basic massifs in this region. In many ways, the University intrusive is unique due to its geotectonic location and geomorphological settings of the bedding formation.

2. Geotectonic location and formation ages of alkaline-gabbroid magmatism in Northern part of Kuznetsk Alatau
There are two structural compositional levels in geological composition of this territory. Lower level is composed by Vendian-Early Cambrian dislocated sediments, which are developed fragmentally in the areas of the most erosional cross section and are represented by carbonate sediments with layers of effusive-sedimentary rocks. They are grouped in narrow linear folds with N-E and submeridional (near N-S) trends, thus correlating to main structures of the region. Upper structural level is represented by volcanogenic formations usually dated as Middle Cambrian. It contains basaltic and andesite rocks, their tufas and high Mg lava breccia. Effusive distribution fields are enriched with alkaline and subalkaline dykes. It is typical for this level sediments to have quite flat inclination (falling angles) of 15-30°. The region has complex block-type composition caused by many disjunctive destructions of different type submeridional trend [13]. There are over 20 expressions of alkaline rocks in this region, which are of certain interest in exploring nepheline ore deposits of different categories (*Fig. 1*).

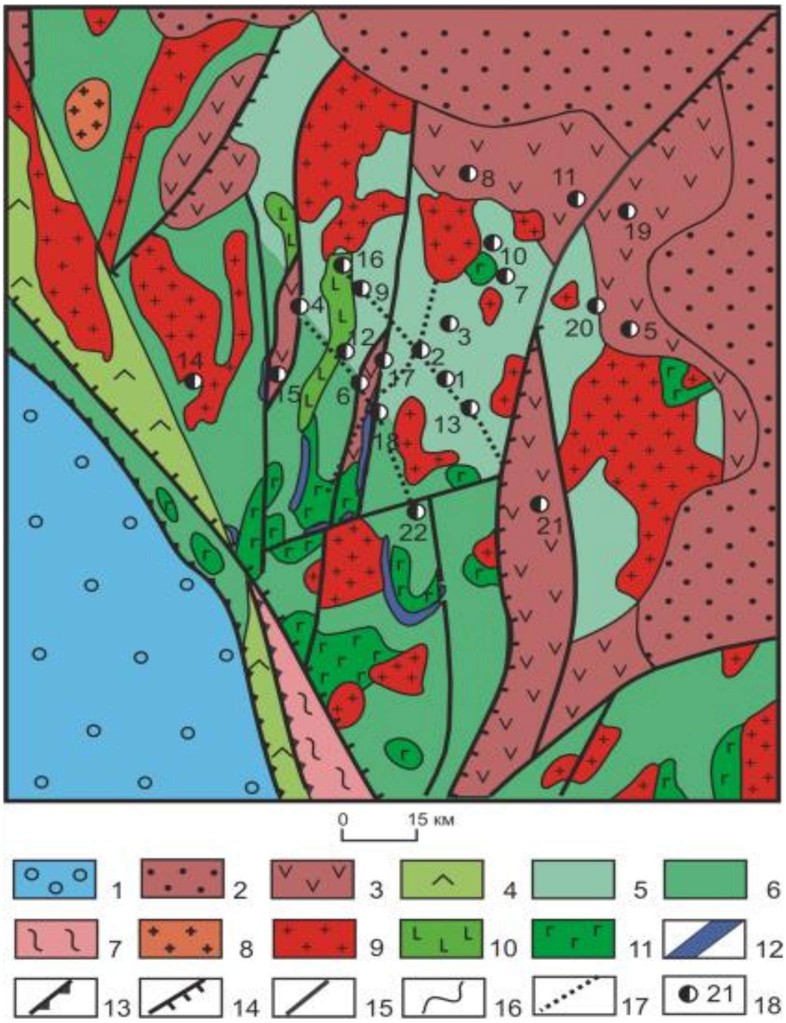

Figure 1. The scheme of placement alkaline basic massifs in geological structures of a northern part of Kuznetsk Alatau [1].

1 – deposits of the Kuznetsk carboniferous deflection; 2 – terrigenous deposits Devonian deyteroorogennic of hollows; 3 – volcanogenic deposits Devonian deyteroorogennic of hollows and grabens; 4 – Ordovician deposits of the Taydonsky graben; 5 – carbonaceous and volcanogenic deposits of the lower and middle Cambrian; 6 – siliceous and slate, volcanogenic and carbonaceous deposits of the top rifeya-lower Cambrian; 7 – average rifeya-high metamorphic complexes of the Tomsk ledge; 8 – superalkalinity granites; 9 – granites of a normal causeticity; 10 – moderate and alkaline gabbroic and syenite; 11 – basits of ophiolit association; 12 – ultramafita of ophiolites association; 13 – thrust; 14 – dumpings; 15 – other tectonic violations; 16 – geological borders; 17 – belts of milkings alkaline basites series; 18 – massifs of the alkaline and main breeds (1 – Kia-Shaltyrsky, 2 – University, 3 – Belogorsk, 4 – Svetlinsky, 5 – Podtayginsky, 6 – "Kiysky exits", 7 – Kurgusulsky, 8 – Batanayulsky, 9 – Verkhnepetropavlovsky, 10 – Cheremushinsky, 11 – Goryachegorsky, 12 – Zagorny, 13 – Dedovogorsky, 14 –. Motley, 15 – Malosemenovsky, 16 – Tuluyulsky and Medvedkinsky, 17 – Malokiyashaltyrsky, 18 – Velvet and Kiysky, 19 – Andryushkina the small river, 20 – Uchkuryupsky, 21 –. Bald, 22 – stream Dmitriyevsky).

One of the typical features of structural localization for these objects is dyke belts with certain trends, which connect real intrusive massifs. Generally speaking, the largest intrusions are located at the intersection of N-W and near N-S trended dyke belts or near them, which correlates to more permeable “magma plumbing systems and “magma concentration” systems or structures. Last ones are considered to be lithological and structural border between Vendian-Cambrian carbonate folded association and overlapping Middle Cambrian volcanogenic bedding thickness. This conclusion is also confirmed by concentration of majority of alkaline-gabbroic intrusives in carbonate substrate.

Only intrusive massifs located in central part of this region (adjacent to Kiya-Shaltyr deposit) correspond fully to criteria of Early Devonian magmatism in Mariinsk Taiga.

3. Specific features of geological composition and petrographic variety variance of the University Massif

In the modern erosional cross section, University Massif is barely exposed; it is located in lower part of relief and overlapped by a high thickness layer of mellow sediments (from 1 to 10 m). Under these conditions, it was extremely challenging to outline the massif and determine features of its geological composition. In order to do so, detailed above ground magnetometric survey was carried out along with major mining operations and core drilling. On a map (*Fig.2*), it is a body stretched in meridional (near N-S) direction (its length is 2.5 km, its width is from 0.2 to 0.6 km), whose structure is significantly complicated by tearing strains. Relationships with host rocks are ambiguous. It is thought that there are mostly tectonic contacts with gabbro and plagiogranites in the Voskresensk intrusion. With limestones from the Ust-Kundatsk Formation, there were fragments of intrusive contacts found, and both tectonic and active magmatic boundaries were seen with vulcanites of the Berikul Formation. In the active contact zone, marling and hornfelsing and propylitic alteration were noticed. Main intrusion phase of the massif is represented by a subalkaline gabbroic body, whose petrographic composition is similar to poikilitic basites of the Kiya-Shaltyr Massif. Other phases are feldspar and feldspar-free foydolites, subalkaline and alkaline gabbroic, nepheline and alkaline syenites that compose many small and sometimes thick (up to 10-30 m) dykes, as well as holocrystalline theralites and ijolites represented by “isometric” body on the eastern side of the massif.

Subalkaline gabbroic, which compose main body of the first intrusive phase, have quite uniform mineral composition and differ mostly in degree of crystallinity. Main rock-forming minerals are olivine, basic plagioclase (An_{50-54}), Ti-bearing augite, biotite and titanium magnetite; accessory minerals are usually apatite and sphene. It has hypidiomorphic-granular texture with elements of poikilo-ophytic and poikilitic textures.

Basic foydolites and theralites have smooth transitions from one to another with different variations in content of nepheline, plagioclase, olivine and pyroxene. Major difference in composition of foydolites and alkaline basites is that nepheline grains have higher degree of idiomorphism than feldspar. Medium-coarse grain theralites of the second intrusive body on the Eastern side demonstrate characteristics of secondary feldspathoids development in plagioclase, whose basicity lowers down to oligoclase-andesine in this paragenesis. This indirectly confirms hybrid nature of these formations. Taking into consideration that there are diluvial drops of almost completely feldspar-free medium-grain ijolites in association with these rocks, we can assume active interaction of later feldspatoid melt with early intrusion stage gabbroids. Additional prove of these rocks belonging to second phase of massif formation is presence of many small dykes if feldspar ijolites and nepheline camptonites (tamaraites) breaking through subalkaline gabbroic of main body and which can be considered as vein facies of feldspar ijolites.

Ultrabasic foydolites within the massif and its adjacent areas are represented by dykes with low thickness (from tens of cm to couple meters). They are mostly located in Western part of University Massif breaking through gabbroic and effusives of Berikulsk association. By compositional and textural characteristics, we can classify them in four main groups: a) phenocryst-free microijolites; b) ijolite-porphyrs with nepheline inclusions from 10 to 30%; c) urtite-porphyrs (with nepheline inclusions 50-70%); d) microijolites with large inclusions (“xenoliths”) of holocrystalline urtites, rarely pegmatoid ijolites and microijolites. “Xenogenic” nature of last ones is suggested based on observations of similar variety of Kiya-Shaltyr deposit dykes, which have sharp contacts with ore body rocks and specific isotopic-geochemical characteristics [3].

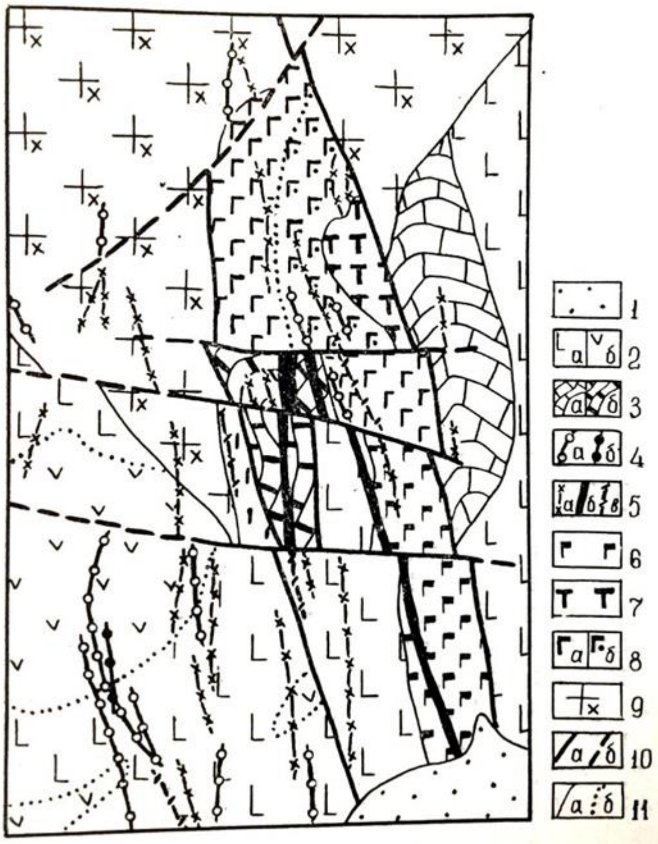

Figure 2. Scheme of a geological structure of the University massif [7].
1 – quarternary alluvial deposits; 2 – middle Cambrian, berekulsky suite: and – basalts, andesitobasalta, dacites, – lavobreccia, their tuffs; 3 – lower Cambrian, lips kundatsky suite: and – limestones, batts, interlay siliceous and batts, – marbles limestones; early Devonian kiysky (goryachegorsky) alkaline gabbro complex: 4 – 5 – high-alkaline dyke: 4 – and – mikroijolita, – urtit porphyries, 5 - feldspathic rocks: and – shallow and microgranular ijolita, - medium-grained ijolita, in – nepheline kamptonita; 6 – alkaline compact-grained porfirovidny gabbros of the facies of endocontact; 7 – leucoteralita with lenses the feldspathic of ijolit; 8 – the gabbro containing nepheline: and – to 5 and – up to 15%; 9 – early Paleozoic Voskresensky intrusion: gabbro, granodiorita, plagiogranita; 10 – tectonic violations: and – traced, - estimated; 11 – geological borders: and – traced, – gradual.

In general, composition patterns of University massif and its rock associations let us assume that this object can be considered as slightly eroded alkaline-gabbroid massif formed on lithological boundary of Early Cambrian carbonate and Middle Cambrian volcanogenic formations.

4. Geochemical characteristics of rocks and geodynamic setting for their formation

Main characteristic of petrogenic oxide distribution in high-alkaline rocks from Northern slope of Kunetsk Alatau is their discreteness demonstrated on «Na_2O+K_2O–SiO_2» diagram *(Fig. 3)*. Variation trends plotted for 13 massifs of this region correspond/correlate to at least three types of petrographic magmatic series:

a) Subalkaline gabbroids – moderate alkaline syenites;
b) Theralites – basic foydolites – nepheline syenites;
c) Feldspar-free melteigites – ijolites – urtites.

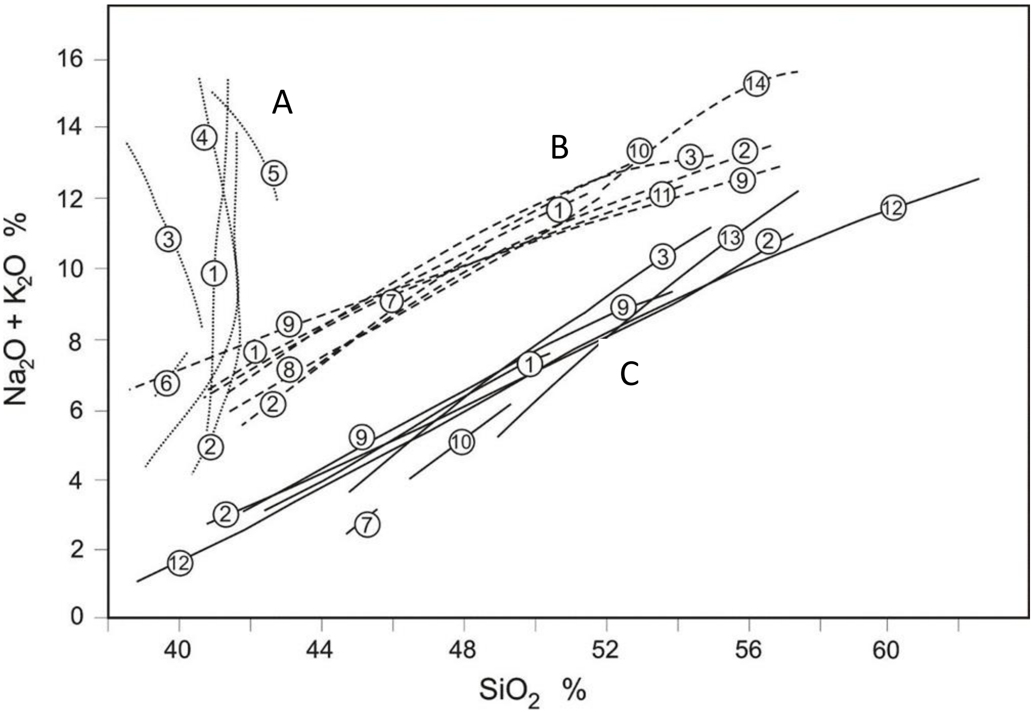

Figure 3. The petrochemical chart "Na2O+K2O-SiO2" (for breeds of alkaline massifs of Kuznetsk Alatau [3].
Legends: (A) variation curves of the ultramain foidolit; (B) variation curves of the main foidolit; (C) variation curves of alkaline gabbroic. Alkaline massifs: 1, Kia-Schaltyr; 2, University; 3, Belogorsk; 4, Svetlinsky; 5, Podtayga; 6, Kiysky exits; 7, Kurgusul-Listvenny; 8, Batanayula; 9, Verkhnepetropavlovsky; 10, Cheremushinsky; 11, Goryachegorsky; 12, Bolshe-Taskylsky; 13, Dedovogorsky; 14, mountain Pestraya.

Different combinations of mentioned series are observed in different geological objects. For example, only rocks of the first series (A) are typical in Barkhatno-Kiysk and Dedovogorsk massifs, only second series (B) in Goryachegorsk massif, and exclusively rocks from third series (C) are present in Svetlinsk massif. There are objects with contrast monolithic chemistry (like Kiya-Shaltyr, Upper Petropalovsk, Kurgusul-Listvenniy massifs) or more diversified massifs, which contain products of all three series. The University intrusive belongs to last ones; it has subalkaline gabbroic, theralites and basic foydolites, as well as ijolity-urtite dyke series. Chemical composition and concentrations of trace elements of representative rock varieties in the studied object are listed in Table 1. Petrogenic oxides were diagnosed analyzed by wet chemical methods and XRF, and rare and trace elements were studied by ICP MS method in Analytic center of geochemistry of nature systems in National Research Tomsk State University.

Table 1. Representative chemical compositions of magmatic breeds of the University massif

Oxide	**1**	**2**	**3**	**4**	**5**
	36/147	41/84.0	8A	UN-1	КС-7/1
SiO2	44,98	47,80	46,46	41,93	41,17
TiO2	0,95	1,055	1,27	0,375	0,49
Al2O3	15,11	19,58	14,71	25,96	28,5
Fe2O3	11,198	9,11	11,34	2,89	4,53
MgO	8,929	4,315	6,92	2,09	2,4
CaO	14,63	14,19	10,53	6,41	7,96

Na2O	2,96	2,8	4,23	10,35	10,24
K2O	0,95	0,39	2,43	9,26	3,28
P2O5	0,093	0,051	0,5	0,301	0,44
LOI	1,13	0,54	1,26	2,89	2,55
Sum	99,8	99,29	99,65	99,566	99,01
Infrequent elements					
Cr	224,1975	37,8801	55,7850	38,8518	19,8222
Ni	55,6799	29,2340	7,2418	6,2617	12,1023
V	155,2618	42,9117	11,7179	8,5373	63,7576
Co	48,4729	34,3551	12,1484	9,1979	14,2550
Cs	0,7782	0,4699	0,9851	0,6854	11,6256
Rb	23,4988	37,9099	41,1832	53,8740	100,1275
Ba	302,8811	345,7155	725,5941	395,4535	280,1494
Sr	537,59	1075,04	885,38	1063,35	35,6995
Nb	9,3328	10,4365	41,2114	12,6448	5,8020
Ta	0,5891	0,7326	2,4440	0,9502	0,4298
Zr	123,5396	95,0487	275,6794	81,0037	69,0379
Hf	2,6788	1,5559	3,9573	0,8246	2,2212
Y	22,3645	17,2153	45,2998	14,8354	8,2749
Th	2,7176	2,4501	7,0018	3,2981	4,1883
U	1,9170	2,2620	5,4251	3,1508	1,3037
Sc	23,6218	6,1947	0,8634	0,5078	5,7854
∑ TR	111,3	94,37	245,97	103,58	79,185
La/Yb	9,691	9,588	10,277	12,419	17,76

Note. 1 – melanocratic gabbro; 2 – leucocratic gabbro; 3 – theralit; 4 – urtit porphyry; 5 – the urtit xenolith from urtit porphyry. Content of oxides (weight %) and infrequent elements (ppm) of RFA and ICP-MS. in "Analytical center of a geochemistry of natural systems" of NI TGU (Tomsk).

Transition elements (siderophile and chalcophile like Cr, Ni, Mn, V, Co, Sc, Cu, Zn). We observe quite low concentrations of these elements in the massif rocks. Their enrichment accumulation level comparing to contents in C1 (chondrite) standard [5]. is generally under one, except for Sc, Ti, and V (*Fig. 4*).

We can see on the diagram "sharp" negative anomalies for iron-group elements (Cr, Co, Ni)– their concentrations are 3 to 1000 times less than in chondritic component, and insignificant positive anomalies for (Ti, Sc, V), whose concentrations in average are 1,5 to 20 times higher than in C1 standard (*Table 2*).

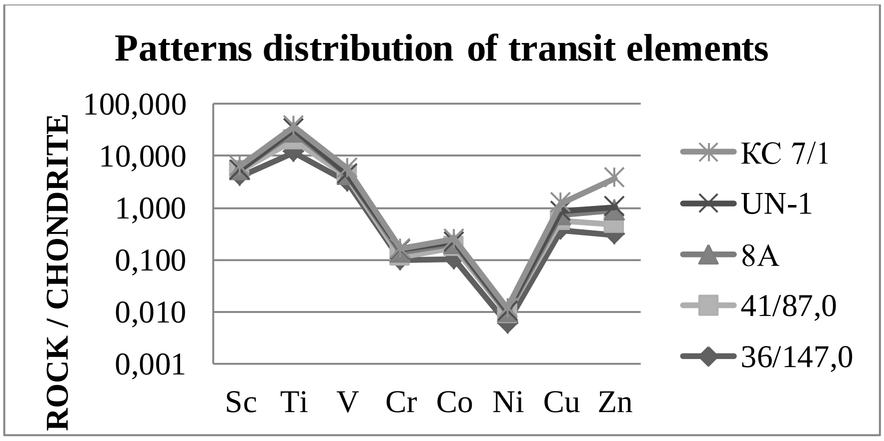

Figure 4. Patterns distribution of transit elements in breeds of the University massif
36/147,0 – melanocratic gabbro; 41/84.0 – leucocratic gabbro; 8A – leucotheralit; UN-1 – urtit porphyry; KC 7/1 – an urtit xenolith from urtit porphyry.
Concentration of a normalized on C1 [5].

Table 2. Distribution of infrequent and rare earths in breeds of the University massif

Rock	36/147.0	41/84.0	UN-1	8A	8A	KC-7/1
Elements	1	2	3	4	5	6
Be	1,503	1,615	2,819	5,217	4,907	0,752
Sc	23,622	6,195	0,508	0,863	0,861	5,785
Ti	4851,3	3369,1	1795,4	3176,9	3314,6	2094,2
V	155,3	42,912	8,537	11,718	10,830	63,758
Cr	224,2	37,880	38,852	55,785	55,505	19,822
Co	48,473	34,355	9,198	12,148	12,643	14,255
Ni	55,680	29,234	6,262	7,242	7,993	12,102
Cu	42,795	21,524	15,711	18,815	20,431	43,856
Zn	106,0	63,5	52,1	139,9	163,0	943,6
Ga	17,17	14,74	20,26	24,97	26,11	7,573
Rb	23,50	37,91	53,87	41,18	42,04	100,13
Sr	537,6	1075,0	1063,4	885,4	899,9	35,7
Y	22,365	17,215	14,835	45,300	44,745	8,275
Zr	123,5	95,05	81,00	275,7	281,5	69,04
Nb	9,333	10,436	12,645	41,211	42,890	5,802
Cs	0,778	0,470	0,685	0,985	1,015	11,626
Ba	302,9	345,7	395,5	725,6	796,6	280,1
La	20,98	17,91	21,76	48,93	47,96	18,97
Ce	44,48	37,76	44,58	101,63	101,74	31,46
Pr	5,205	4,514	4,919	9,161	9,104	3,737
Nd	21,23	17,56	17,85	44,12	43,30	14,33
Sm	4,545	3,395	3,097	8,532	8,541	2,746
Eu	1,321	1,385	1,039	2,717	2,630	0,721
Gd	4,412	3,191	2,732	8,088	8,041	2,144
Tb	0,700	0,516	0,432	1,334	1,316	0,320
Dy	4,267	3,124	2,619	8,311	8,095	1,926
Ho	0,881	0,663	0,578	1,788	1,761	0,379
Er	2,440	1,908	1,690	5,094	5,039	1,063
Tm	0,357	0,295	0,268	0,784	0,769	0,162
Yb	2,165	1,867	1,752	4,761	4,806	1,068
Lu	0,317	0,285	0,264	0,715	0,706	0,163
Hf	2,679	1,556	0,825	3,957	4,065	2,221
Ta	0,589	0,733	0,950	2,444	2,507	0,430
Th	2,718	2,450	3,298	7,002	6,717	4,188
U	1,917	2,262	3,151	5,425	5,692	1,304

Note. Breeds are presented: melanocratic gabbro – 36/147; leucocratic gabbro – 41/84.0; urtit porphyry – UN-1; leucotheralit – 8A; ijolit with "xenolith" urtit porphyry. Concentration of minerals (ppm) are determined by the ICP-MS method in "Analytical center of a geochemistry of natural systems" of NI TGU (Tomsk).

Rocks in the massif demonstrate the following pattern of transit element distributions. In genetic sequence “leucocratic - melanocratic gabbro”, concentrations of all elements decrease from samples 41/84.0 to 36/147,0. Moreover, comparing with gabbroic in leucotheralite (sample 8A), urtite porphyry (sample UN-1) and xenolith (sample KC-7/1) have higher concentrations of transit elements. It should also be noted that there is high concentration of zinc in sample Kc-7/1 (ijolite with xenolith of urtite) comparing to other samples.

Specific characteristics of trace element behavior in rocks of University massif are shown on multi-elemental diagrams demonstrating patterns of REE, LILE and HFSE distribution. When plotted these graphs plots, primary analytical data was normalized by CI and OIB standards according to [9].

Spectrum graphs of lanthanide distributions for rocks from University massif are characterized by very tight ratios of light to heavy elements (*Fig. 5*). They are almost parallel to each other and correspond to La/Yb ratios of 10 to 18. Total REE enrichment accumulation level corresponds to the following. The least depleted ones are urtite inclusions (“xenoliths”) from ijolite dykes (sample Kc-7/1) that correlates to the data on urtites from Kiya-Shaltyr intrusive [10]. In urtite porphyry, concentration of these elements is a little higher, and it keeps increasing in subalkaline gabbroic. At the same time, melanocratic gabbro is more enriched in rare earth elements than leucocratic gabbro. In last one, a week positive anomaly of Europium is observed. Such pattern can be explained by cumulative segregation of nepheline in foydolites and plagioclase in gabbroids as early crystallization stages of the melts.

Maximum level of enrichment accumulation is in leucotheralites, whose graph plot is kind of isolated. It could be the result of mixing of magmatic melts with different compositions.

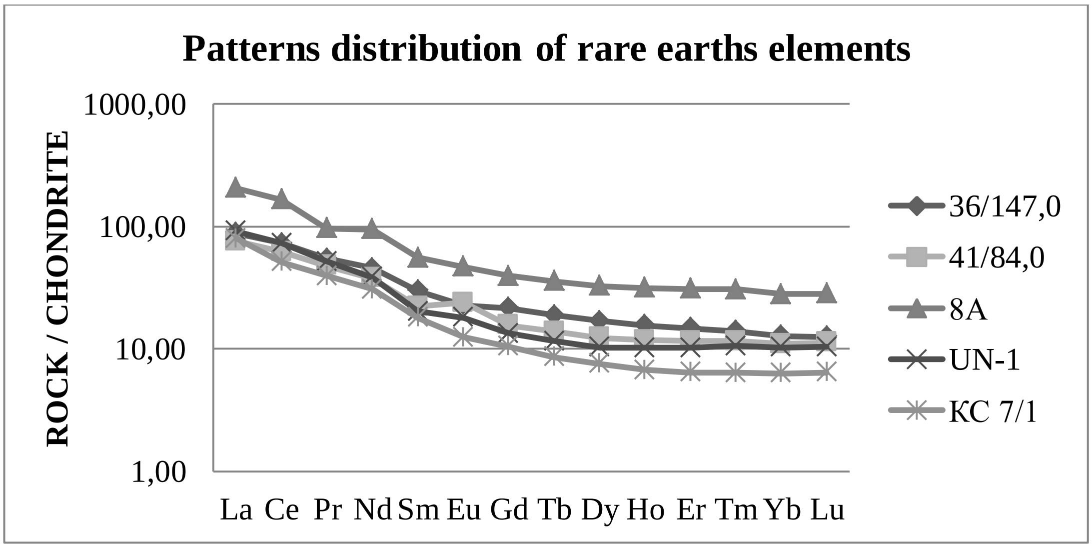

Figure 5. Distribution of rare earths in breeds of the University massif
36/147,0 – melanocratic gabbro; 41/84.0 – leucocratic gabbro; 8A – leucotheralit; UN-1 – urtit porphyry; KC 7/1 – an urtit xenolith from urtit porphyry.
The maintenance of REE is normalized on CI [9].

Multi-elemental graphs plots spectrums normalized by average OIB composition show following patterns. Foydolites (samples KC-7/1 and UN-1) demonstrate quite fast sharp depletion in most rare elements comparing to OIB standard (*Fig. 6a*). Higher concentrations are seen in LILE and U. Similar behavior is observed in multi-elemental graphs for subalkaline gabbroic, but at a slightly higher concentrations of rare elements (*Fig. 6b*).

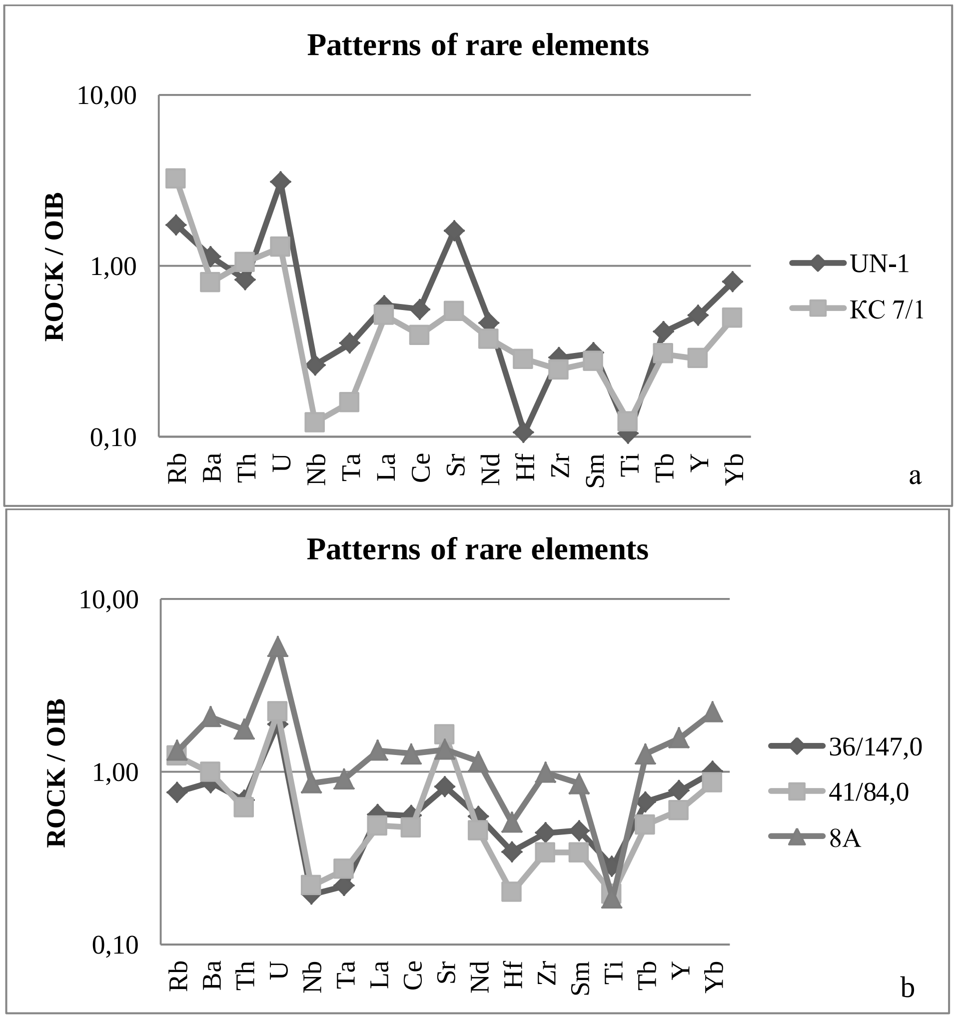

Figure 6. Patterns rare elements in breeds of the University massif
(a) Foidolita: UN-1 – urtit porphyry; KC 7/1 - "xenolith" of the urtit from ijolit porphyry.
(b) The gabbro, theralit: 36/147,0 – melanocratic gabbro; 41/84.0 – leucocratic gabbro; 8 A – leucoteralit;
Contents the rare of elements are normalized on OIB [9].

The closest to OIB graph is distribution in leucotheralites (sample 8A), where there is no fast enrichment in Sr. In general, presence of distinct negative anomalies of Nb, Ta, Hf and Ti with steep positive peaks of Rb, Sr and U indicate quite complex geodynamic setting for formation of Devonian alkaline rocks in Mariinsk taiga. It is very possible that generation of primary magmas took place in setting of active thermal interaction of mantle plumes and lithosphere mantle with further participation of crust matter and crust fluids [4].

Therefore, specifics of trace element distributions in rocks from University massif allow us to correlate them with analogue products from Kiya-Shaltyr and adjacent massifs (Dedogorsk and Belogorsk). Deficiency in niobium, tantalum, hafnium (appear as steep negative anomalies) along with generally lower mantle plum component normalized to OIB, as well as local enrichment in LILE (Sr, Rb, Ba) suggest complex geodynamic settings of alkaline-basic magmatism in central part of Kuznetsk

Alatau in Early Devonian. Similar conclusions were made by D.N. Voitenko while interpreting geochemistry of rocks from Kiya-Shaltyr massif [10].

5. Isotopic dating

Sm-Nd Method. Sm and Nd isotopic composition was measured on 7-channel solid-phase mass spectrometer Finnigan-MAT 262 (RPQ) in static double strand mode using rhenium and tantalum strands [8]. Average ratio of $^{143}Nd/^{144}Nd$ in La Jolla standard during period of measurements was 0.512081±13 (N = 11) *(Table. 3)*. Errors in values of (2 σ) $^{147}Sm/^{144}Nd$ do not exceed 0.5 %, and 0.005 % for $^{143}Nd/^{144}Nd$. During calculation of primary isotopic ratios and ε_{Nd}, ε_{Sr}, T_{Nd} (DM) values, modern parameters of model standard reservoirs CHUR ($^{143}Nd/^{144}Nd$ = 0.512638, $^{147}Sm/^{144}Nd$ = 0.1967) and depleted mantle (DM) ($^{143}Nd/^{144}Nd$ = 0.51315, $^{147}Sm/^{144}$ Nd = 0.2137) were applied [2].

Table 3. Isotope structure of Sm-Nd in the gabbro of the University massif

Exemplar	Concentration, mkg/g		Isotope relations		T_{DM}, million years	$\varepsilon_{Nd}(T)$
	Sm	Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$		
			C36/147			
WR	3.42	15.27	0.1353	0.512808±9	498	+7.3
Pl	1.531	9.46	0.0978	0.512709±16		
Ol	4.49	13.23	0.2050	0.513051±10		
Px	4.18	15.02	0.1682	0.512922±8		
			C41/84.0			
WR	1.769	7.46	0.1433	0.512907±12	492	+8.7
Pl	0.588	3.44	0.1033	0.512797±9		
Px	2.43	7.99	0.1841	0.513041±25		
Ol	3.95	11.020	0.2165	0.513160±12		

Note. C36/147 – melanocratic gabbro, C41/84.0 – leucocratic gabbro.

Isochrones were built by D. York’s method [14] using Isoplot/Ex software [6]. More precise Sm-Nd isochrones were obtained by mineral phases and whole rock compositions of two samples of subalkaline gabbroic (*Fig. 7*).

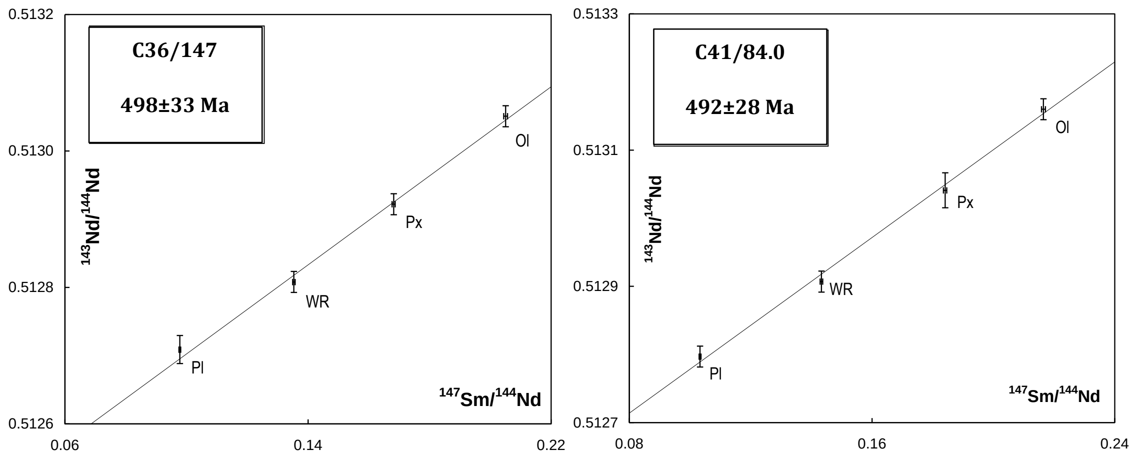

Figure 7. Sm-Nd mineral isochrones on subalkaline gabbroic of the University massif. Measurements were taken by a reference technique [8].

One of the biggest surprises during this research was the actual age of studied gabbroids, which is 498-492 ±23-28 Ma. Such expression of alkaline magmatism in this region took place exclusively in western part of Mariinsk Taiga and was recorded in alkaline-gabbroid association of Upper-Petropavlovsk Massif [11]. Dating alkaline rocks by Sm-Nd isotope method nowadays is quite complicated because variations in $^{147}Sm/^{144}Nd$ values do not exceed 0.09-0.11 range. However, we can conclude that their formation occurred in Devonian (380 – 430 Ma), and this age corresponds to the main stage of foydolite expression in this part of the region. An important element in studying University massif is its intermediate structural location between western and eastern sectors of areas of high-alkalinity magmatism expression on the Northern slope of Kuznetsk Alatay, which were formed during long period of time (507 -265 Ma) according to recent geochronological research [12]. We assume a case of several stages pulses of high-alkalinity magmatism within this geological object. More detailed studying will promote design of geodynamic model of high-aluminous alkaline magmas formation under settings of mantle plume activity in folded structures of ancient continent margins.

6. Conclusion

The results of conducted research let us make following conclusions, which reflect necessity of further studying of alkaline-gabbroic University massif. First, this object is of big interest for justifying locations of nepheline ore deposits in this region. Specifics of its geological composition and location at the border between two associations of carbonate and volcanogenic series, which have very different dislocation levels and petrographic material compositions, allow us to understand study composition of upper part of intrusive front of alkaline-gabbroic magmatism. Second, broad petrographic and petrochemical rock-forming variety provides for reconstruction of genesis process of high-aluminous minerals in magmatic complexes of this region. Third, detail geochemical testing promotes development of a more accurate geodynamic model of high-alkalinity magmatism expression in folded structures of Northern and Central Asia.

This work was conducted as a government task of the Ministry of Education and Science of the Russian Federation Project Number 5.2352.2017/4.6

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