UDC 552.3:550.4:550.42:550.93

PETROLOGY AND GEOCHEMISTRY OF ADAKITIC GRANITOIDS ALEISKII COMPLEX OF RUDNY ALTAI (SIBERIA)

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Abstract. Tonalites, plagiogranites and plagioleicogranites of Aleiskii complex (Early Carboniferous age) of Rudny Altai carry to adakite granitoids on mineral and chemical composition. All rocks of it complex ascribe to high-SiO_2 type adakite. The adakite granitoids of Rudny Altai carry to rocks high aluminous type. Parent source melting of adakite of Rudny Altai was quartz eclogites. Generating of adakite granitoids and geodynamic setting of forming adakites region connected with function of plum source at high pressure ($P \geq 10$-12 kbar). Generation of adakite granitoids connected with mantle- crust interaction at acting of "Andersonian plum".

Key words: adakite granitoids, tonalite, plagiogranite, plagioleicogranite, plum source, mantle-crust interaction.

INTRODUCTION

Specific acidic intrusive rocks fall in to it type granitoids, detecting similarity with volcanic adakites. Very low concentrations of Y (≤ 18 ppm), Yb (≤ 1,8 ppm), increased contents V and Cr, high ratios $(La/Yb)_N$ normalized to chondrite (more 8-10), indicating on strong differentiation type distribution REE in rocks. Adakites has significant practical meaning because with their connected deposits of copper-porphyre, epithermal gold-copper in the copper-porphyre belt of Gandizi in Tibet, gold black shale ore mineralization deposit of Bakyrchik in Eastern Kalba (Republic Kazakhstan) [10]. The acidic differences of concluding phases forming of massives Aleiskii complex (C_1) carry to adakite granitoids in Rudny Altai. *The main aim* of the research is to study petrology, geochemical features of adakites granitoids Akeiskii complex.

RESULTS OF INVESTIGATION

Rocks of complex date to Aleiskoe emergence that there are in limits compose Aleiskii and north-east periphery part Antoshihinskii massive. Three phase intrusions detached ours in composite of complex: 1) gabbro, gabbro-norites, gabbro-pyroxenites, gabbro-diorites; 2) tonalities, granodiorites; 3) plagiogranites and plagioleucogranites. The petrotypic mezoabyssal Aleiskii massive arrange in north-east area of central part an Aleiskoe emergence and it extend from south-east to north-west on distance more 100 km at width 10-30 km. This massive characterize by an inhomogenitic relative gravitation and an inhomogenitic magnetic fields [5].

Gabbro of first phase form xenoliths (about 5 km^2 on square) of irregular form among granitoids of Aleiskii massive and break through metamorphic rocks of Korbalikhinskaja suit (S-

D_1). Rocks consist (%) from variable amounts labrador-bitovnite (25-60), clinopyroxene and green hornblende (20-35), gypersthene (40), antigorite and magnetite on olivine (6-10). Composition of rocks Aleiskii complex bring in table 1. Gabbro treat to low – Ti magnesium (FeO*/MgO=0,8) low-K differences. Content of REE correspond gabbroids of primitive island arc with depleted on Y and HREE.

Table 1

Representative chemical compositions of adakite granitoids Aleiskii complex (oxides in %, elements in ppm)

Components	Tonalites			Plagiogranites				Plagioleicogranites		
SiO_2	66,3	67,38	66,6	70,93	69,6	70,04	70,1	75,34	75,64	74,95
TiO_2	0,55	0,46	0,48	0,32	0,39	0,37	0,38	0,25	0,18	0,27
Al_2O_3	14,82	16,96	15,23	14,02	15,32	15,73	14,91	12,6	13,12	12,85
FeO*	5,28	4,2	4,0	4,44	3,61	4,0	3,55	3,28	2,61	2,53
MnO	0,12	0,06	0,09	0,11	0,07	0,05	0,10	0,07	0,18	0,11
MgO	1,99	2,0	2,9	0,9	1,1	1,86	2,33	0,53	0,54	0,93
CaO	5,16	4,2	3,5	3,73	3,51	3,82	3,42	2,22	2,14	1,97
Na_2O	4,57	3,4	4,87	4,1	3,95	2,97	3,98	3,84	3,38	4,12
K_2O	0,79	0,99	0,85	1,0	1,3	1,01	1,10	1,63	1,94	1,27
P_2O_5	0,10	0,06	0,05	0,18	0,19	0,11	0,10	0,04	0,07	0,08
Sum	99,95	99,97	99,87	100,0	99,96	100,03	100,0	99,93	99,97	99,98
Li	10,5	10,9	11,1	12,5	11,0	16,6	15,5	15,7	15,5	14,8
Be	0,9	0,91	0,93	2,1	2,0	1,12	1,93	2,1	2,2	2,0
Sc	4,9	4,78	5,1	3,3	2,9	8,64	6,7	7,3	7,5	7,2
V	55	50	52	40	40	50	40	35	32	33
Cr	40,1	37,5	38,3	24,8	26,0	34,1	30,2	23,1	21,5	20,7
Co	7,3	7,03	7,2	6,5	7,3	3,63	4,3	3,4	3,2	3,1
Ni	11,6	11,1	11,3	6,7	7,0	6,47	6,5	6,1	6,0	5,8
Cu	7,2	6,97	7,0	15,4	16,0	15,1	15,3	16,6	16,4	16,0
Zn	38,7	36,6	38,2	39,3	40,0	43,2	41,8	44,1	45,3	40,3
Ga	21,0	20,4	20,7	13,8	13,5	14,2	13,7	13,1	14,2	13,7
Rb	15,9	15,7	16,3	25,7	12,8	39,8	29,4	16,3	17,5	18,0
Sr	340	337	342	305	310	175	287	253	261	273
Y	5,8	7,64	6,2	3,7	2,3	4,3	8,5	2,2	2,1	1,97
Zr	18,5	19,2	19,1	40,6	59,8	44,5	43,7	57,8	55,1	56,2
Nb	3,2	3,22	3,12	3,2	2,35	8,0	4,2	4,1	4,0	3,8
Cs	0,4	0,43	0,41	0,48	0,5	0,85	0,6	0,9	0,91	0,83
Ba	160	150	170	257	230	351	352	355	360	370
La	7,55	8,63	9,9	16,7	12,4	17,7	15,7	16,8	17,0	16,5
Ce	19,7	20,0	20,2	21,3	19,4	33,1	25,4	34,2	33,5	35,1
Pr	2,4	2,49	2,5	3,95	3,9	4,05	4,1	4,3	4,2	4,1
Nd	11,0	10,4	10,7	9,6	8,4	15,2	14,3	15,5	15,1	15,2
Sm	2,5	2,23	2,3	2,3	1,78	2,93	2,57	1,81	1,8	1,78
Eu	0,88	0,76	0,81	0,75	0,66	0,86	0,9	0,8	0,82	0,9
Gd	2,12	2,02	2,2	1,7	1,6	2,97	2,5	1,9	1,85	1,86
Tb	0,40	0,29	0,31	0,3	0,24	0,51	0,48	0,4	0,41	0,37
Dy	1,62	1,54	1,61	2,9	3,0	3,09	2,95	2,7	2,6	2,5
Ho	0,33	0,28	0,32	0,53	0,65	0,66	0,63	0,6	0,55	0,57
Er	0,77	0,76	0,79	1,96	2,0	2,04	1,95	1,92	1,9	1,84

Tm	0,18	0,12	0,15	0,28	0,3	0,31	0,25	0,28	0,27	0,25
Yb	0,75	0,72	0,71	0,34	0,42	1,12	0,23	0,35	0,33	0,24
Lu	0,11	0,1	0,12	0,13	0,06	0,31	0,25	0,2	0,18	0,19
Hf	0,65	0,68	0,70	2,2	2,6	1,52	1,97	2,5	2,4	2,3
Ta	0,22	0,23	0,24	0,4	0,2	0,46	0,37	0,3	0,32	0,31
Pb	4,2	3,71	3,8	10,3	10,1	9,84	10,2	12,5	12,8	12,4
Th	0,15	2,0	2,3	3,8	2,2	4,61	5,1	4,8	5,2	5,2
U	0,15	0,16	0,15	0,25	0,4	0,72	0,65	0,65	0,51	0,31
Sr/Y	58,6	44,1	55,2	82,4	134,8	40,7	33,8	115,0	124,3	138,6
Mg#	0,27	0,32	0,42	0,17	0,23	0,32	0,4	0,14	0,18	0,27
Th/U	14,7	12,5	15,3	15,2	5,5	6,4	7,8	7,4	10,2	16,8
V/Sc	11,2	10,5	10,2	12,1	13,8	5,8	5,9	4,8	4,3	4,6
$(La/Yb)_N$	6,7	7,92	9,2	32,5	19,7	10,4	45,3	31,7	33,9	45,6

Major element abundences in mas. %. Trace element abundences in ppm. FeO*= $FeO+Fe_2O_3$. Trace element analyzed by method laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) in Laboratory of FGUP VSEGEI (c. Saint Petersburg).

The following phases of forming rocks massives Aleiskii complex has petro-geochemical characteristics adakite granitoids.

Tonalities of second phase compose insignificant part of Aleiskii and north-east part of Antoshihinskii massives. These are coarse differs light-gray and gray painting. Between their predominant sharp hornblende, biotite-hornblende, hornblende-biotite tonalities, proceeding in granodiorites. Content of tonalities (%): quartz (20-22), biotite and hornblende (15-20), plagioclase (45-55), potassium feldspar (1-3). The accessory minerals insert: magnetite, seldom – ilmenite, titanite, zircon, apatite. The high contents (ppm) Cr (from 37,5 to 40,1), V (from 50 to 55), Sr (337-342) and ratios Sr/Y (44-58), $(La/Yb)_N$ (6,7-9,2) and so low concentrations Y (5,8-7,64), Yb (0,71-0,75) are characterized for tonalities, disclosing relationship to adakites. The endocontact facies of massives represented by contaminate quartz diorites and tonalities.

Plagiogranites of third phase are light-gray, massive, coarse-, coarse-grained, seldom middle-grained, sometimes with primary directional structure, expressing in bedding-plane of enriching by dark minerals. They consist (%) from zone (№ 30-32 in the centre and № 17-19 on the rims) plagioclase (45-60), quartz (25-40), biotite (4-15), hornblende (3-10), potassium feldspar (2-10). Plagioleucogranites and subordinate leucogranite decorate by high content potassium feldspar (15-30) and quartz, and low – dark minerals, plagioclase and smaller basic of plagioclase. The accessory minerals insert: ilmenite, seldom – magnetite, hematite, titanite, zircon, apatite. The fabric of rock is granitic with elements of granoblastic and kataclastic. The tonalites and plagiogranites are characterized by increased aluminous (Shand = 1,08 to 1,2), low mafic index (FeO*/MgO = 2,1-3,3), potassic and high anorthite (c=0,53-0,4). The increased concentrations (ppm) of Cr (24-34,1), V (40-50), ratios Sr/Y (33,8-134,8), $(La/Yb)_N$ (10,4-45,3) and low concentrations Y (3,7-8,5), Yb (0,23-1,12) are property for plagiogranites. More high ratios Sr/Y (115-138,6) and $(La/Yb)_N$ (31,7-45,6) observe in the plagioleicogranites.

All rocks characterized by high ratio Th/U, that it ts show on presence of thorite and that it rocks did not changed by hydrothermal processes. Presence of ilmenite in adakitic granitoids indicate on reduced system, generating of its rocks [11].

Contents of majority rare elements and ratio Rb/Sr (0,1) are characterized for M-type granites, but they are not agree M-type on distribution REE (high level differentiation heavy and light lanthanoids without Eu minimum) are close island arc I-type granites and continental trondhjemites (important to note , that it is presence accessory ilmenite instead magnetite there is not characteristic for I- and M-types of granites). The sharp depletation on Y and heavy REE in the most aluminous differentiation differences suppose presence garnate in restite in process melting depth source. On this situation point to absent zones of quenching, width contact aureoles amphibol-hornfel facies (to 3 km) and migmatization, and so small values indicator ratios geochemical polar elements (Be/Co = 0,22, La/Sc = 2,4, Be/Ba = 0,005). Material content of rocks and other signs are close to gabbro-plagiogranite formation (they distinguish by subordinate role of gabbro and width spread leucocratic differenriations in rocks of main phase, concerning to adakites).

The early carboniferous age of complex set outcoming from intruding of rocks Korbalikhinskaja suit of Silurian - early Devonian, absent active contacts with Emsian and more young depositions. Absolute data of rocks Aleiskii complex received in result geochronologic studies (U-Pb dating zircons, «classic» method, GEOCHI RAS, analytic E.V. Bibicova; dating single grains of zircons, SHRIMP-II, VSEGEI name A.P. Karpinskii, analytic A.V. Lepekhina; Ar-Ar dating of amphibol and biotites, Analitic Center of OIGGM SO RUS, analytic –A.V. Travin), descending in limits analytic mistakes data 322-318 mln. years [4, 7, 12, 13].

Rock types of Aleiskii complex on classification of H. Martin [12] treat to high-SiO_2 adakites (HAS) with very high ratios SiO_2/MgO (from 72 to 95) (Fig. 1).

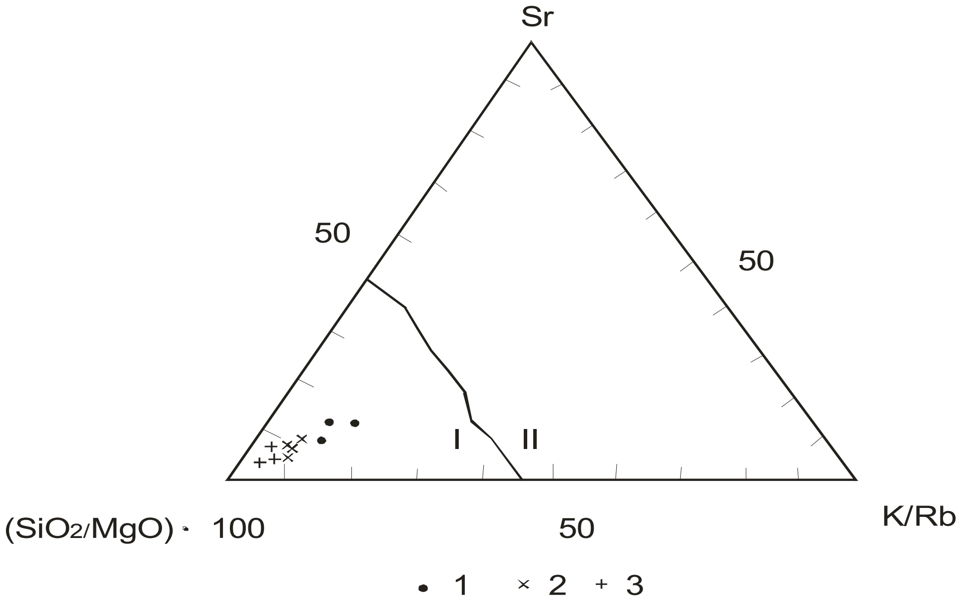

Fig. 1. Plot Sr – (SiO_2/MgO)·100 – K/Rb after [14] for adakite granitoids of Rudny Altai

Fields of adakites: I – high-SiO_2, II – low-SiO_2. Rocks of Aleiskii complex: 1- tonalities, 2- plagiogranites, 3- plagioleicogranites.

Strong depletation of Nb and Ti with negative anomalies observe in composite of HFSE in felsic rocks of Aleiskii massive Rudny Altai. Adakite granitoids on the diagram K – Rb has trend of ratios K/Rb from 389 to 1100, showing K - Rb fractionation and concerning depletation by Rb in it process. The increasing ratio of K/Rb in adakite granitoids of Rudny Altai observe with increase content of K, that it is characteristiclly for high magnesium adakites from area Baja California [14].

Tetradic effect fractionation (TEF) of rare earth elements M-type of first tetrad discovery, vary from o,96 to 1,31 (тable 2). The TEF REE M-type in adakites related with anomalous parameters of fluid regime and high contents of fluor.

Table 2

Tetradic effect fractionation of rare earth elements and ratio of some elements in rocks Aleiskii complex Rudny Altai

TEF REE, ratio of elements	1	2	3	4	5	6	7	8	9	10	Values in hondrites
TE_1	1,07	1,05	0,97	1,03	1,31	1,0	0,96	1,06	1,04	1,07	-
Y/Ho	17,6	27,3	19,4	7,0	3,5	6,5	13,5	3,7	3,8	3,4	29,0
Zr/Hf	28,5	28,2	27,3	18,4	23,0	29,3	22,2	23,1	22,9	24,4	36,0
La/Nb	2,3	2,7	3,2	5,2	5,3	2,2	3,7	4,1	4,2	4,3	17,2

La/Ta	34,3	37,5	41,2	41,7	62,0	38,5	42,4	56,0	53,1	53,2	16,8
Sr/Eu	386	443	422	407	470	203	319	316	318	303	100,5
Eu/Eu*	1,15	1,09	1,1	1,13	1,19	0,89	1,09	1,33	1,38	1,52	1,0
La/Lu	69	86	82	128	207	57	63	84	94	87	0,975

TE_1 – Tetradic effect fractionation of rare earth elements for *first tetrad after [8]; normalized to hondrite after [1]. $Eu^* = (Sm_N + Gd_N)/2$.* Rocks of Aleiskii complex: 1- tonalities, 2- plagiogranites, 3- plagioleicogranites.

On the plot of ratio Te_1 – Eu/Eu* figures of points rocks of Aleiskii complex Mountain Altay show increasing TEF REE M-type in relating with increasing values (fig. 2).

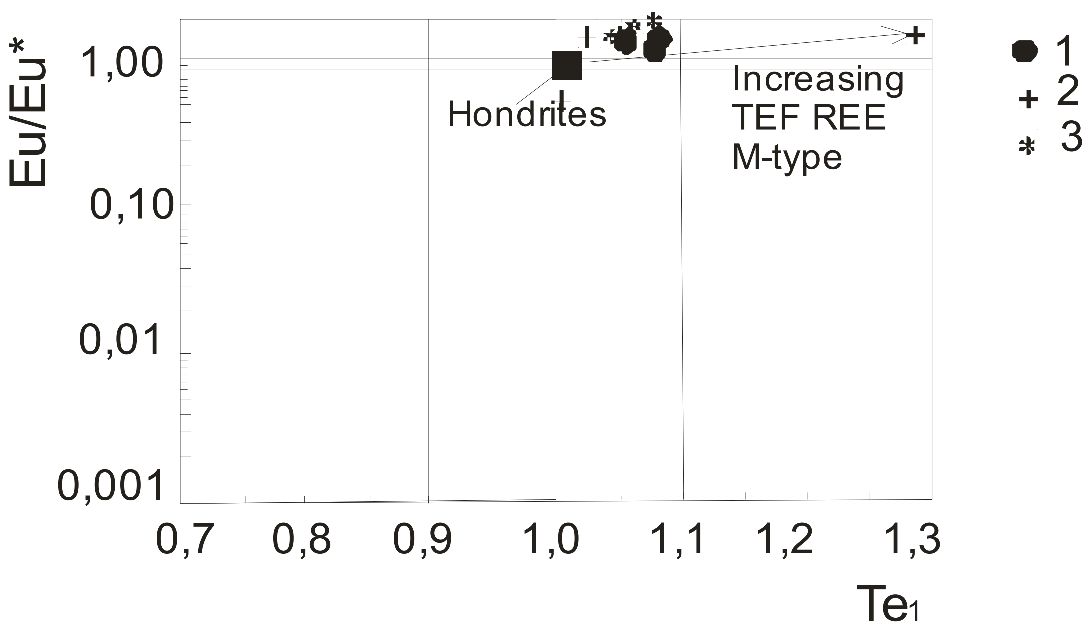

Fig 2. *Eu/Eu* - Te_1 for rocks of Aleiskii complex of Rudny Altai*

Other symbols are as in Fig 1.

INTERPRETATION OF INVESTIGATION

On the plot of ratio La – Nb compositions of adakites of Aleiskii complex fall to lithosphere and asthenosphere fields (Fig 3). It data point out on the of mantle and crust interaction.

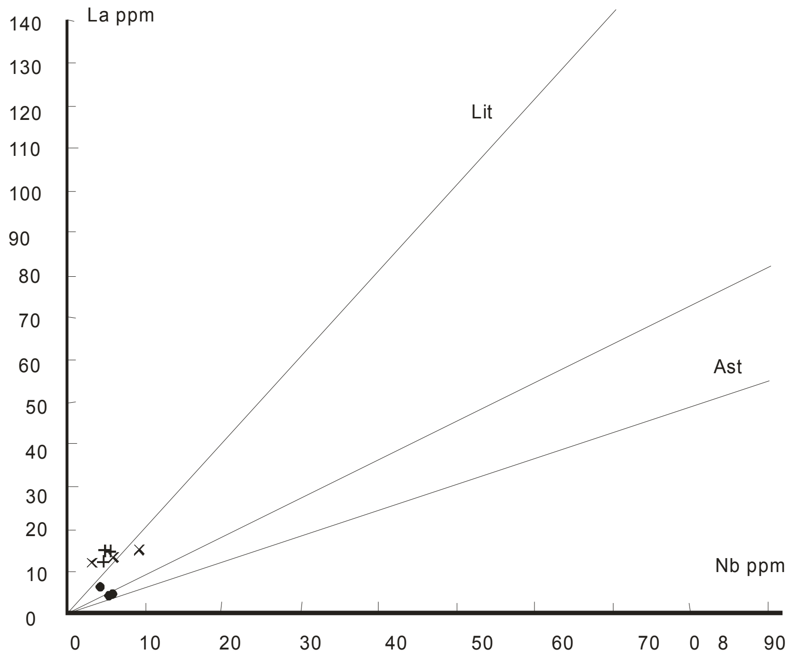

Fig. 3. Plot La – Nb after [7] for rocks of adakite granitoids of Aleiskii complex

Other symbols are as in Fig 1.

Ratio of (La/Yb) – $(Yb)_N$ show that adakites of Aleiskii complex get on the trend of melting of quartz eclogites (fig. 4).

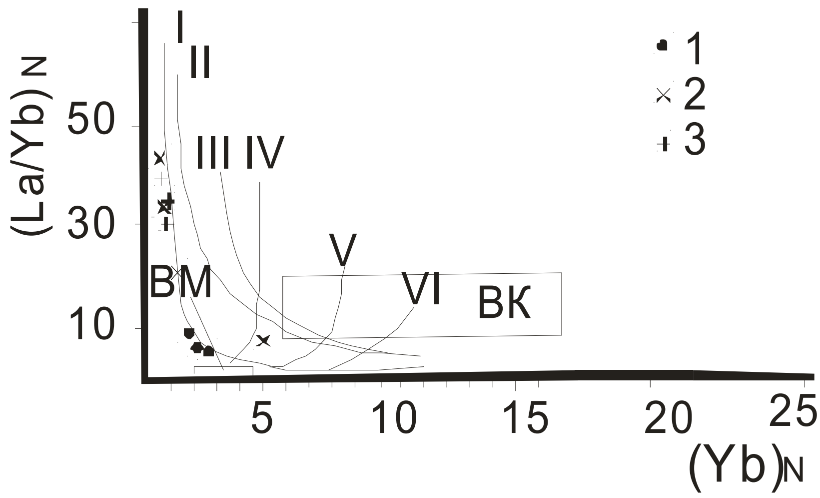

Fig. 4. Plot of ratio $(La/Yb)_N$ - $(Yb)_N$ after [3] for rocks of adakite granitoids of Aleiskii complex

Trends of melting different sources after [3]: I- quartz eclogites; II – garnet amphibolites; III – amphibolites; IV – garnet-contenting mantle with content of garnet 10 %; V – garnet-contenting mantle with content of garnet 5 %; VI – garnet-contenting mantle with content of garnet 3 %; BM – upper mantle; BK – upper crust.

Other symbols are as in fig 1.

Ratio of La/Nb – Ce/Y show that generation of adakites happen composed scenario: melting of mantle source and mixing with crust material (Fig. 5). Adakites granitoids of Rudny Altai at it exponents are similar to adakites of Sumsunurskii batholite of Eastern Sajan [6].

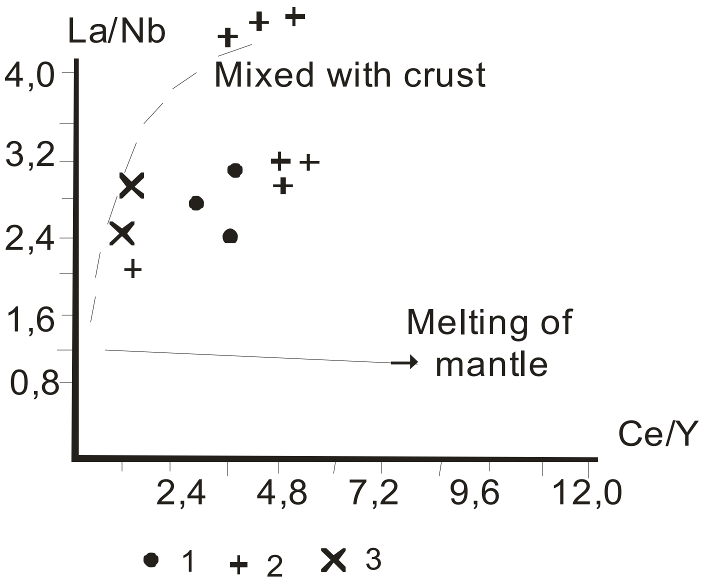

Fig. 5. Plot ratio La/Nb – Ce/Y after [3] for adakite granitoids of Aleiskii complex

Other symbols are as in Fig 1.

Petrology of adakite granitoids and their forming after ocean stage of developming of Rudny Altai allow suppose that plum situation account "Andersonian plum" [2], forming in upper mantle level, but it is not from deep low mantle (D" layer). Plum setting linked with near 670 discontinuity at the base of the upper mantle and arousing of asthenosphere.

CONCLUSION

Rock types of Aleiskii complex on classification of H. Martin treat to high-SiO_2 adakites (HAS). High contents of aluminous (Al_2O_3= 14,9-16,96) in tonalities and plagiogranites, improverishing heavy REE and Y testify about adjunct their to rocks high aluminous type, that there are produce in communication with dewatering (dehydratation) and melting metabasic rocks at P≥10-12 kbar [15]. Parent source of melting of adakites of Rudny Altai was quartz eclogites. The tetradic effect fractionation of REE M-type detached in rocks. Petrogenetic models and geodynamic setting of forming adakitic granitoids of Rudny Altai connect: 1) with slab melting of metabasic rocks, localizing on the border mantle and earth crust, or 2) melting delamination garnet-content of low continental earth crust. In both occurrences the melting can realize only at presence powerful thermal mantle flow, connected with function plum source of "Andersonian type".

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