Composition and conditions of the late Mesozoic volcanism occurrence of the northern part of the Borschovochny ridge (Eastern Transbaikalia)

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Composition and conditions of the late Mesozoic volcanism occurrence of the northern part of the Borschovochny ridge (Eastern Transbaikalia)

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Abstract. On the basis of geochemical study results composition heterogeneity and formation conditions of late Mesozoic subvolcanic rocks from northern part of Borschovochny ridge by an example of shadoronsky and abgatuysky complexes are discussed. Obtained results show that volcanic rocks of both complexes have heterogeneous composition and differ from each other in level and other features of alkalinity. Rare and trace elements geochemistry study results show that there is a significant enrichment with LILE (Cs, Rb, Ba) and some depletion with HFSE (Nb, Ta), meanwhile the correlation between Th and Yb indicates conditions of active continental margin. Gd/Yb and La/Sm ratios allow to conclude that shadoronsky complex rocks originated from garnet-stable mantle source (partial melting of 5% of garnet peridotite), while abagatuysky complex rocks originated from transitional garnet-spinel mantle.

1. Introduction

Eastern Transbaikalia has complicated geological structure. One may consider this region as combination of geotectonic zones of different age considered from the point of view of plates and and terrains geodynamics. According to data on tectonic zoning, there are following structural elements taking part in the structure of the region: active continental margin of Siberian craton (zone of Stanovoy range) at the north, Argunsky microcontinent at the south, in the central part [1, 2].

Mongol-Okhotsk fold belt is the suture zone that appeared at the junction of Siberian craton and Argunsky microcontinent (figure 1) [3]. On the territory of studied area it's presented by Hantay-Daursky and Aginsky terrains [1]. Aginsky terrain is bounded by disjunctive faults system from all sides, which formed as a result of collision processes in Siberian craton – Argunsky microcontinent system. Such activation ongoing throughout all Mesozoic period conditioned complexity of the terrain structure. There is a series of blocks overthrusted on Argunsky microcontinent. In such a way, that collision stage was ended with general rise of the terrain, followed by major granitization and paleoocean closure.

Borschovochny ridge, which is made up of granitic rocks, and some dissimilar rocks complexes together are known as Borschovochnoe upland. This upland takes important role in the whole structure of Aginsky terrain. Northern margin of the upland is a conjunction of metamorphic rocks spread zones (urulginsky complex, PR_1), local dynamometamorphites belts (aginsko-borschovochny complex, PZ_3) and superposed mesozoic depressions (K_1). Herewith structure of the last two is complicated with appearance of subvolcanic rocks of shadoronsky (J_{2-3}) and abagatuysky (K_1) complexes.

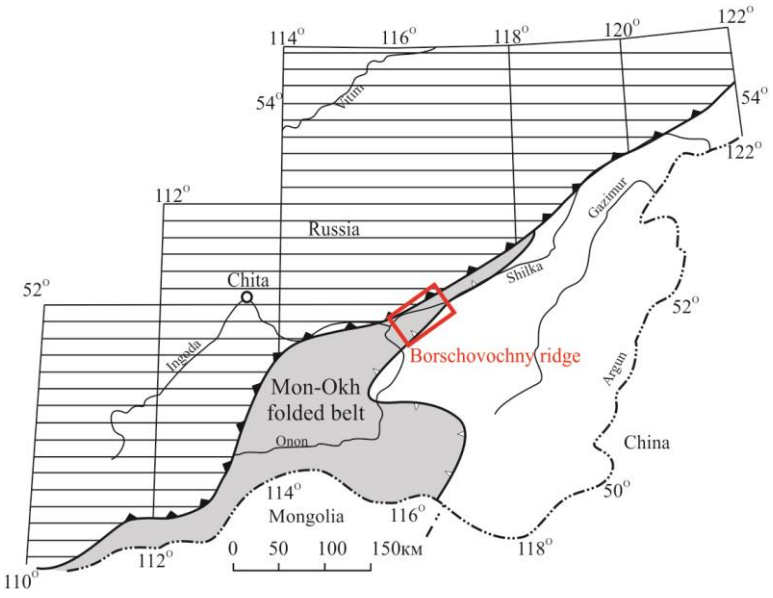

Figure 1. Location of Borschovochny ridge in structures Mongol-Okhotsky folded belt

2. Geological setting and composition of subvolcanic rocks

Subvolcanic rocks of shadoronsky andesite-dacite complex are localized in area of distribution of dynamometamorphic rocks of aginsko-borschovochny complex at the northern part of Borschovochny ridge framing. There are sill-like bodies and high and medium angle dipping dikes of dacites and andesidacites. Vast majority of subvolcanic bodies has north-east strike. Some single dikes have latitudinal strike. Transgressive magmatic bodies have smaller thickness (varying from a dozens of centimeters to 10-15 meters) in comparison with subconcordant ones.

As a result of petrographic study of the shadoronsky complex rocks two groups of them were distinguished. The first group includes porphyritic and aphyric andesites. The second group includes more felsic kinds of rocks – dacites and dacite porphyries.

Andesites are massive or poorly foliated cryptocrystalline rocks with brownish grey colour, often with shades of green. Presence of short-prismatic grains 1-2 mm size of white-coloured plagioclase on a background of cryptocrystalline bulk is the characteristic feature of the rocks. Overall amount of phenocrysts (5-7 mm size) in porphyry kinds of rocks doesn't exceed 10-15%.

Dacites are light brown and homogeneous in the bulk with up to 2 mm long phenocrysts made up of quartz, feldspar, muscovite, less often – biotite. Dacite porphyries differ from dacites by significant increase of plagioclase phenocrysts size up to 5 mm. The bulk of rock is composed of quartz, feldspar, mica, hematite and iron hydroxides and has microlitic/felsitic structure.

Trachybasalts and rhyolites of abagatuysky complex are located within bounds of mesozoic superimposed depressions, which are located at the north-west edge of Borschovochny ridge and filled with turginskaya suite rocks (K_1). Extrusive rocks lie at the bottom of turginskaya suite. There are dikes, thin veins, small stock-like and funnel-like bodies with basalt-andesite and dacite-rhyolite compositions, less often there are their alkaline kinds. Abagatuysky complex rocks act as feeders for turginskaya suite formation and break through its rocks both in the mesozoic depression. Dikes and dike-like bodies are from first meters to 250 meters thick, their strike length may reach 1,5 km. Stock-like and funnel-like bodies sizes are from hundreds of meters to 1-1,5 km across [4].

In terms of petrography there are two kinds of rocks among abagatuysky complex rocks: andesites and microgranites. At that there is possibility of porphyric and aphyric kinds of meta-andesites appearance as among shadoronsky complex rocks.

Microgranites belong to felsic kinds of abagatuysky complex rocks. There are microporphyry xenomorphic quartz phenocrysts not more than 0.8 mm size, which may occupy to 15% of rock

volume in the number of samples. The bulk of the rock is composed of plagioclase, quartz and potassium feldspar.

In terms of chemical composition shadoronsky and abagatuysky complexes rocks are well differentiated. There are low TiO_2 (0,3-1,4 wt. %), P_2O_5 (0,09-0,7 wt. %) contents, rather high Al_2O_3 (12-17 wt. %) content. Total silica amount varies within 50-72 wt. % range. Alkali amount varies отwithin 3,9-5,7 wt. % range (3,7-9,4 wt. % in abagatuysky complex rocks). It is shown on the $Na_2O + K_2O – SiO_2$ diagram (figure 2a) that there are two groups of points for abagatuysky complex. First group is located within bounds of from trachyandesibasalts to trachytes field. The second one is within from fields of basalts to fields of rhyodacites. Shadoronsky complex rocks match with medium alkaline rocks of abagatuysky complex. At the same time both complexes differ significantly by kind of alkalinity. Shadoronsky complex rocks mainly are potassium-sodium containing while abagatuysky complex rocks mainly are sodium containing (figure 2b).

Rare and trace elements geochemistry study reveals that accumulation of most of LILE (Cs, Rb, etc.), Th and U and moderate HFSE contents are characteristic for both complexes (figure 3b, d). Elements behavior pattern corresponds mostly to peculiarities of rare elements composition CIAB type source [5] with spectral minima Nb-Ta and Zr-Hf (for a number of samples from shadoronsky and abagatuysky complexes). Concentrations of Cs, Rb and Ba are increased due to their rather high solubility in aqueous fluid in subduction zones. Maxima of Th and U (which are HFSE elements) are there because both the elements behave in subduction environment as «non- conservative» ones [6]. Since Th solubility degree in subduction zone fluid is particularly low, it is considered that this element was taken from sedimentary component of submerging plate. Sr concentrations and rather high total LILE amount are peculiarities of both complexes. In comparison with primitive mantle, in shadoronsky complex samples there is higher enrichment with large ion lithophile elements and positive Sr correlation. At the same time there is an opposite tendency in abagatuysky complex, medium LILE concentrations and Sr minimum. Such differences probably are related to tectonic evolution of the region that expressed in subduction processes replacement by rifting processes and, as a result, decrease of subduction component in abagatuysky complex geochemistry.

Rare earth elements are widespread in both complexes (figure 3a, c). Shadoronsky complex rocks have medium total REE content (ΣREE = 80-130 ppm) with significant predominance of LREE over HREE ($La/Yb_{(N)}$ = 19-29, REE contents are chondrite-normalized according to [7]). For abagatuysky complex rocks total amount of REE varies in 113-240 ppm range; $La/Yb_{(N)}$ ratio is 2,6-10, spectra disposition is complicated by slight negative Eu anomaly (Eu/Eu* = 0,67-0,8).

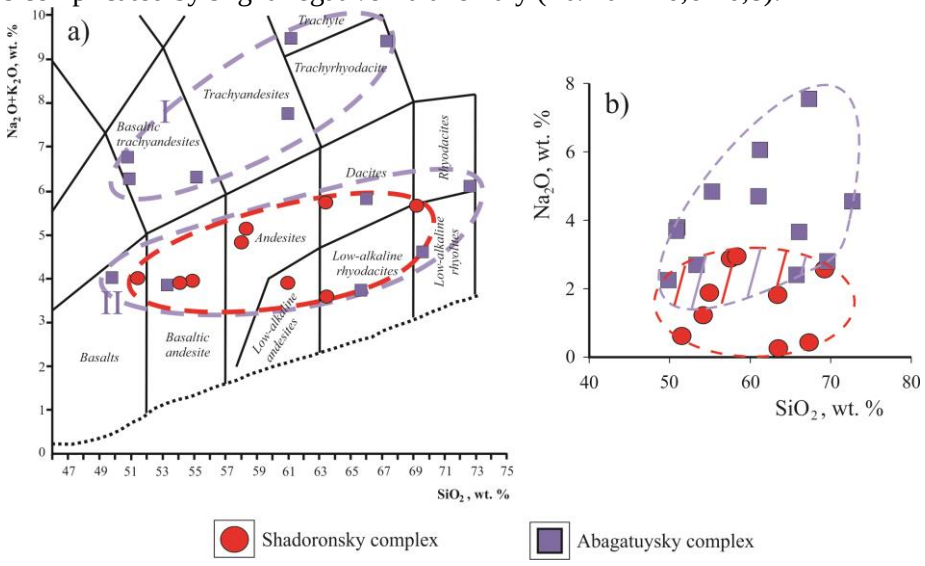

Figure 2. The classification diagrams (Na_2O+K_2O) – SiO_2 (a) [8] and $K_2O – SiO_2$ (b) for the volcanics of the shadoronsky and abagatuysky complexes

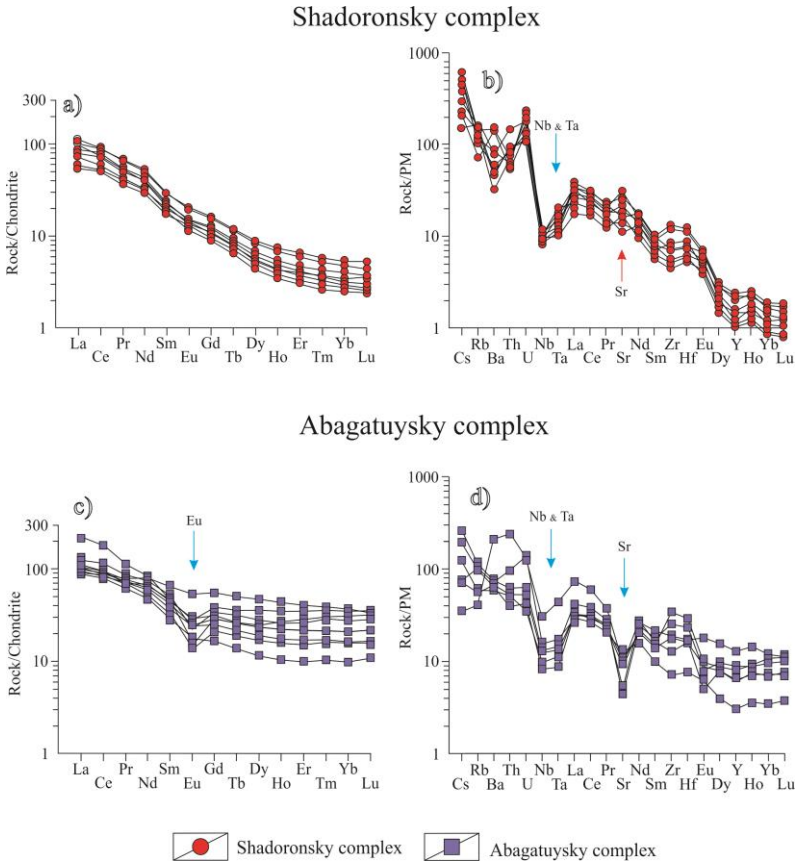

Figure. 3. Chondrite-normalized [12] REE patterns (a - shadoronsky formation, c - abagatuysky formation), and primitive mantle-normalized [7] multi-element spectra (b - shadoronsky formation, d - abagatuysky formation)

3. Volcanism conditions and source composition

Geodynamic nature of shadoronsky and abagatuysky complexes was considered by variation diagrams composing in Th/Yb - Ta/Yb, Th/Ta – Yb coordinates (figure 4a, b). Shadoronsky complex rocks belong to active continental margin field (ACM), while abagatuysky complex rocks have their source shifting from ACM field to within plate volcanic zone (WPVZ) field. Such points shifting over the ACM-WPVZ boundary may be caused by significant influence of crustal component. Besides that, such shifting may reflect complicacy of tectonic nature of the region where evolution from low angle subduction to extension conditions took place. Since that volcanic complexes, which are related to low angle subduction, have their points located within ACM field, while other volcanic complexes, which are related to extensional volcanism phase, have their points lying within WPVZ field. In our case abagatuysky complex rocks are likely to be transitional ones and include andesites (related to subduction) and felsic rocks (related to rifting) [9]

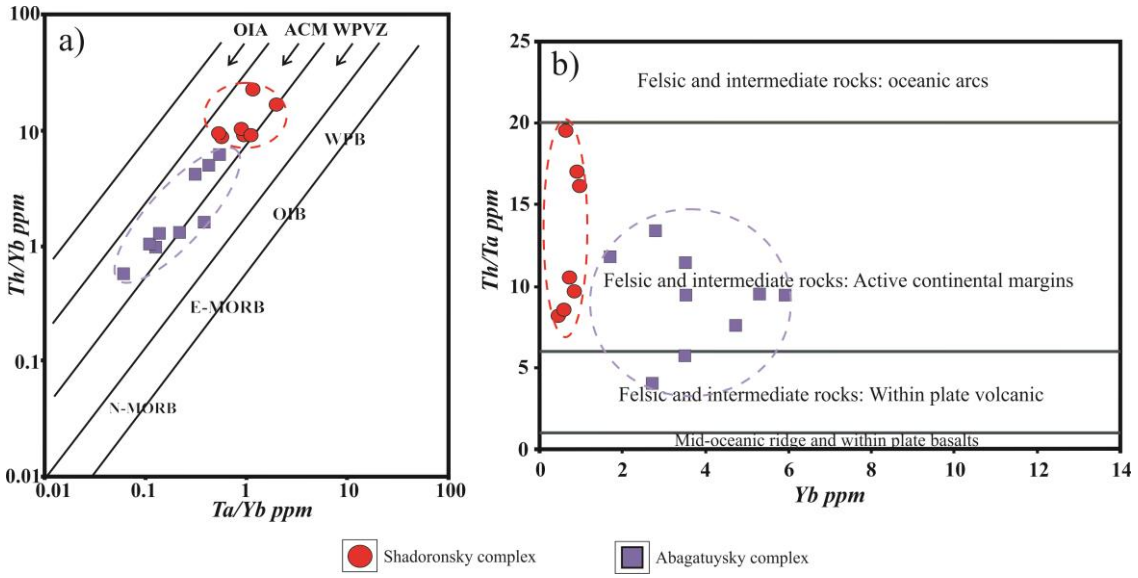

Figure 4. Geochemistry diagrams: a) Binary diagram Th/Yb-Ta/Yb (ACM (active continental margin), OIA (ocean island arcs), OIB (basalts of oceanic islands), E - MORB (basalts of mid-ocean ridges), WPVZ (Intraplate volcanic zone), WPB (within plate basalts)) [9]; b) Binary diagram Th/Ta – Yb [9]

Partial melting degree of studied complexes may be estimated by rare earth elements composition. Heavy rare earth elements (HREE) are compatible in garnet, while middle rare earth elements (MREE) are imcompatible or poorly compatible [10]. On the contrary, all REE are imcompatible in spinel [11].

In such a way, magmas from stable garnet source have higher Gd/Yb ratios than those of magmas from stable spinel source. On the other hand, Gd/Yb and La/Sm ratios may be increased while fractional crystallization of mafic minerals and plagioclase, so low Gd/Yb and La/Sm ratios would become rather close to initial ratios of primary magmas [12].

Calculations show that abagatuysky complex rocks were formed within the overlapping zone between garnet mantle and spinel mantle about 80-110 km deep (figure 5). Yet it is hard to estimate partial melting degree with use of positions of points on the diagram. In accordance with Gd/Yb relations shadoronsky complex rocks could formed of mantle source, which has high portion of garnet in its composition (about 200-300 km deep). Moreover, such modeling shows that these rocks formed by partial (5 %) melting of garnet peridotite.

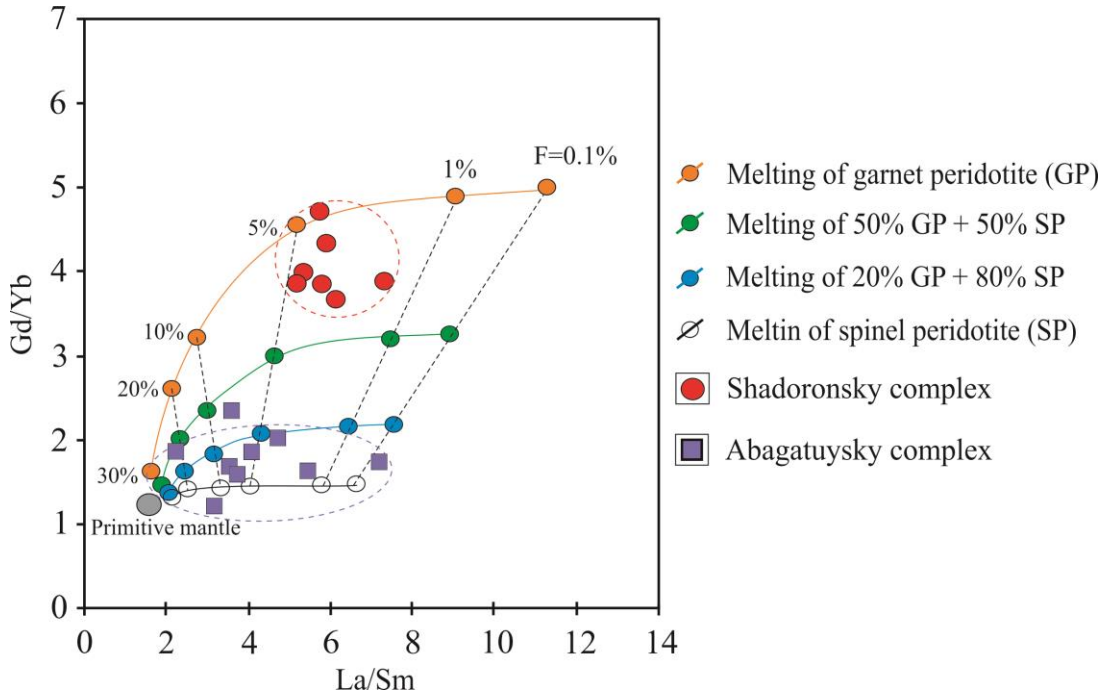

Figure 5. Scattergram of Gd/Yb ratios vs La/Sm ratios of the rocks shadoronsky and abagatuysky complexes. Primitive mantle and the lower crust compositions are from Sun and McDonough (1989) [12]

4. Conclusions

(1) Studied subvolcanic rocks of shadoronsky and abagatuysky complexes are differentiated with SiO2 contents in the 50-72 wt. % range and alkali contents in 3,7-9,4 wt. % range. At that increased alkalinity (6,2-9,4 wt. %) with sodium specificity is observed for abagatuysky complex rocks.

(2) Rare and trace elements geochemistry study reveals significant enrichment with LILE, what expresses in positive anomalies of Cs, Rb и Ba contents, which are caused by influence of aqueous environment of subduction zones. Lower HFSE contents with clearly expressed negative Nb-Ta anomaly, as it's supposed, are attributes of mantle source with composition alike to that of volcanic rocks of island arcs. Direct correlation of Th and U contents is because of involvement of sedimentary component of oceanic crust in melting process. Divergence between Zr-Hf and Sr contents may be related to abyssal changes of melting conditions, in other words – to geodynamic environment changes.

(3) Th/Yb relation indicates that studied rocks formed in conditions of active continental margin. However, emerging trend of abagatuysky complex samples shift to intraplate volcanic zones field means that in terms of geodynamic model the region transformed from subduction zone to riftogenic situation. Similar model had been suggested for west coast of USA, Rocky Mountains region. Many researchers draw the analogy between that territory and territory of Eastern Transbaikalia, which undergone similar transformations.

(4) Findings on studied rocks source composition indicate that shadoronsky complex rocks probably formed as a result of partial melting of garnet peridotite from up to 300 km deep, while abagatuysky complex rocks formed as a result of partial melting of spinel peridotite in depleted lithospheric mantle in conditions of relatively low pressure (80-110 km).

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