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# Material composition of the basalt-trachyte series of the early Devonian of the Saralin graben-rift

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**Abstract.** The article clarifies the structural-tectonic position of the Saralin graben. It is determined that, along with the Balyksinsky graben located to the south and the Goryachegorsky volcanic plateau to the north, they are the connecting structural links between the Kuznetsk-Alatau alkaline province and the adjacent Minusinsk trough. In the early Devonian, the alkaline province was formed as a vaulted-block structure (the "shoulder" of the rift), and the Minusinsk deflection as a depression with the dominant volcanism in it. The boundary between these positive and negative structures was the deep Balyksinsko-Saralinsky fault.

In the stratigraphic section of the graben, the lower molassoid part (Ustkundustylskaya stratum), the middle trachybasaltoid stratum (Bazarskay) and the upper problematic Ashpanian stratum are distinguished. In addition to analcime basalts, a large extrusive-subvolcanic dome-shaped construction of trachytes is considered.

By petrographic and material composition, volcanites of graben are represented by the dominant basalt-trachyte series in the composition of basanites, trachybasalts, trachyandesites, trachytes. The rocks of the basalt-andesite-basalt-andesite series are limited. Foidites are rare.

Geochemical data indicate the genetic relationship of the volcanics of the studied series. Geochemically, they are clearly specialized in Sc, Ti, Zn, Zr, Th, U, Mn and P. According to the content of some of these elements, the rocks may have an industrial potential.

In geodynamic and genetic plans, graben and its volcanics were formed during plume-tectonic processes involving mantle plume, enriched mantle, and recycling processes of these formations with the substance of the consolidated PR-PZ<sub>1</sub> cortex.

## 1. Introduction

The study of the Saralin graben seems topical for a number of reasons: 1) This graben, along with other grabens of the north-eastern part of the Kuznetsk Alatau (Rastayskiy and Talanovsky), is the largest and lies with them in a single structural paragenesis (figure 1); 2) Together with the volcanic plateau located to the north of the Goryachegorsky volcano plateau, the Saralinsky graben is a connecting structural link between the constituent parts of the widely known Kuznetsk-Alatau volcanic-plutonic alkaline province, represented by the volcanic-terrigenous sequences of early Devonian molassoids of the grabens and plateaus listed, a set of alkali-gabbroic plutons, and so the same associated with them and autonomous extended swarms and belts of dikes of alkaline rocks [1] 3) The Saralinsky graben and the Goryachegorsk volcanic plateau are composite structures of the Severo-Minusinsk depression and thus directly testify to the spatio-temporal and structural connection of magmatites and structures of the Kuznetsk-Alatau province with the Minusinsk trough, which in turn is the largest structure of the axial depression zone of Tuvinsko - Minusinsko-Zapadno-Siberian rifto-continental system [2, 3]; 4) Together with Balyksinsky, the Saralinsky graben traces the Balyksin-Saralin deep fault, which is a submeridional branch from the Kuznetsk-Alataus transregional lineament stretching in the axial zone of the Kuznetsk Alatau. This branch of the fracture dissects the



ridges of Baikalides ( $R_3$ , V), salairid, and also contains lenticular fragments of ophiolites. 5) Graben volcanics are represented by a basalt-trachyte series of rocks, considered one of the indicators of the structures of continental reefs. In the northern part of the graben there is a large extrusive-subvolcanic body of trachytes, while in other grabens of the region trachytes are present mainly as dikes; 6) Saralinsky graben is part of the same ore region, in which there are large deposits of indigenous (gold-sulphide-quartz type and Karlin type) and alluvial gold, copper-molybdenum ores, promising ore occurrences of other minerals. A number of deposits and ore occurrences are located in the immediate vicinity or even in the instrumental parts of the graben.

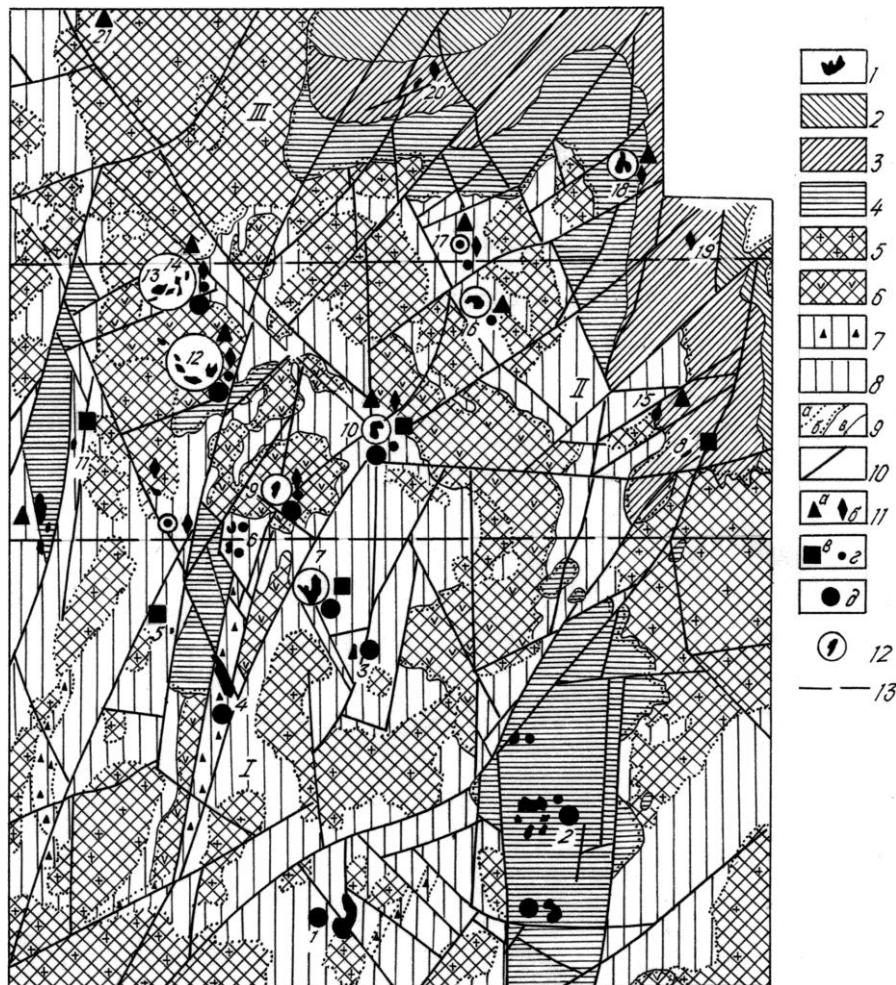


Figure 1. Scheme of the geological-tectonic structure of the north-eastern part of the Kuznetsk Alatau [1]

Upper structural floor ( $D_{1,2}$ ): 1 – plutons of alkali-gabbroic rocks; 2 – 4 – strata of terrigenous-volcanogenic rocks of the lower Devonian: 2 – Ashken, 3 – Bereshskaya, 4 – Bazar. The average structural floor ( $C_{1,2}$  – O): 5 – gabbro, diorite, granite, syenite intrusions; 6 – stratified formations: thicknesses of the Poltava suite ( $C_{1,2}$ ) and mainly volcanics of the Berikul suite ( $C_2$ ). Lower structural floor ( $R_3$  –  $C_1$ ): 7 – Lower Paleozoic hyperbasite intrusives (ophiolites); 8 – stratified formations of salairid with horstobrazovannymi protuberances baikalid ( $R_3$  –  $C_1$ ). 9 – geological boundaries: a – contours of intrusive massifs, b – interformational angular disagreements, c – intraformational angular disagreements, 10 – tectonic disturbances, 11 – main varieties of rocks of alkaline-gabbroic plutons: a – nepheline syenites, b – basic foidolites, ultrabasic foidolites, g – teralites, d – alkaline gabbros. 12 – complex-differentiated alkali-gabbroid plutons. 13 – boundaries of conditionally allocated zones of an alkaline province: I – southern zone, II – central zone, III – northern zone.

Sequence numbers of plutons of alkaline rocks: 1 – p. Dmitrievsky, 2 – Lysoy, 3 – Dedovoy, 4 – Velvet-Kiya, 5 – Kiy outlets, 6 – Malo-Kiya-Shaltyrsky, 7 – Kiya-Shaltyrsky, 8 – r. Podtega, 9 – University, 10 – Belogorsky, 11 – Svetninsky, 12 – Upper Petropavlovsk, 13 – Tulujsky, 14 – Medvedkino, 15 – Uchkuruk, 16 – Kurgusul, 17 – Cheremushinsky, 18 – Goryachegorsky, 19 – Andryushkinoy small rivers, 20 – r. Semenovskiy, 21 – r. Wet Berikul.

Specialized petro-geochemical studies of volcanic graben, as well as other volcanic-tectonic structures of the Kuznetsk-Alatau province, were not subjected, unlike the rocks of alkali-gabbroic plutons, which are systematically studied – O M Grinev, I F Gertner, V V Vrublevsky and other employees of the Geological and Geographical Faculty of the TSU [4, 5, 6, 7, 8].

In this communication, the authors give a brief geological description of the Saralin graben and the first results of a geochemical study of its magmatites. More detailed information on the geology of grabens can be found in the works [2, 9, 10, 11].

## 2. Brief description of the geology of the Saralin graben

*Structural-tectonic position.* The tectonic position of the Saralinsky graben and its direct analogue of the Balyksinsky graben is determined by their confinement to the zone of the deep Balyksin-Saralinsky fault, which has a complex structure in the form of "stratification" into divergent and converging branches, and complicates their disturbances. In the structural plan, the zone of this fault is the western boundary of the Minusinsk inter-mountain trough. On this fault from the axial zone of the Kuznetsk Alatau, the Batenyovsky Ridge is cut off, which, together with the Belyksky protrusion, divides the Minusinsk trough-the Northern and Southern ones-into two halves. At the same time, the Saralinsky graben with its southern part is structurally connected with the southwestern extremity of the North Minusinsk depression, and Balyksinsky with the same tip of the South Minusinsk depression, thereby emphasizing their unity with the Minusinsk trough.

In terms of Saralinsky graben has a linearly elongated lenticular shape. Its southern, most extended, part is gradually narrowed to complete wedging. In the upper reaches of the river. Black Iyus graben undergoes a knee-like inflection. The northern and middle parts of the graben are most extensive, but in the northern part it also quickly wedges out and is cut off by a diagonal north-eastern fault. Further to the north, along the strike of the graben, there are small remains of basaltic covers, transgressively overlapping the folded strata of the pre-Devonian basin. Their presence suggests that the northern extremity of the graben in its original form had a longer continuation, but in a significant part was destroyed by erosion.

Almost along the entire length of the eastern and western sides, the graben is bounded by the branches of the Balyksinsko-Saralinsky fault and only in the northeastern part of the graben's thickness it partially extends beyond the zone of the instrumental fault, transgressively lying on the rocks to the Devonian base. Throughout, the contacts of the graben with the rocks of the pre-Devonian basin are torn off by tectonics and worked by valleys of rivers. Especially it is typical for its eastern side. It is noteworthy that the river valleys in the southern part of the graben are of a trough character, indicating the manifestation of glacial activity. In the northern part, the graben is divided by transverse and diagonal faults into several slightly moved blocks. Judging by the totality of the characteristics, these transverse disturbances detach from the main body of the graben tectonic block, in which there is a large extrusive-subvolcanic body of trachytes.

The dimensions of the graben along the strike are about 123 km, while the width in the northern part is up to 13 km. In the relief, the graben is expressed in the form of a medium-high mountain ridge, about 600-900 m high, with the presence of adherent ridges 900-1,200 m in height to 1,302.2 m (Lysoy Mountain Range, etc.). Absolute elevations of the ridges from the river rills in the middle and northern parts of the graben vary from 300 to 400 m in the south to 630 m in the north.

## 3. The material composition of volcanic graben

Petrochemical features of rocks. According to limited data, published in the work [12], the volcanoes of the main composition are mainly basalts and are limited to the picrobasaltes and andesibasaltes.

The content of SiO<sub>2</sub> in basalts varies within the range of 45.28 - 53.37%, in the microbasalts it drops to 40.06%, and in the andesibasalt increases to 55.98%. The rocks are characterized by high titanium content (1.72-2.42%), medium and high alumina (15.71 - 18.51%), elevated iron deficiency (Fe<sub>2</sub>O<sub>3</sub> - 10.2 - 13.72%, FeO - 3.95 - 7.06% ), average calcium content (4.63 - 10.67%), surprisingly low magnesia (0.16-0.24%) and obviously abnormal Mn (4.75 - 8.07%), (possibly this is a technical error, the content of MgO is indicated instead of MnO and vice versa). Unprecedented for volcanoes are also the contents of P<sub>2</sub>O<sub>5</sub> (3.0 - 7.29%). The content of alkali in the rocks corresponds mainly to the subcellular series, one analysis is characterized by phoid alkalinity, and the second is Tolleitian. In general, the data on the petrochemical composition of basalts of the Saralya require a re-examination and addition.

In TAS diagrams basalts form separate fields of figurative points. Most of them are located in adjacent fields of tefrites and trachibasalts. By the ratio of alkalis, the basalts are sodium (Figure 3, a, b).

Extrusive trachetes (14 analyses) Are characterized by the following content of petrogenic oxides: SiO<sub>2</sub> varies from 57.96 to 63.5%, TiO<sub>2</sub> from 0.63 to 1.36%, Al<sub>2</sub>O<sub>3</sub> from 15.00 to 17.58%, Fe<sub>2</sub>O from 2, 59 to 11.34%, FeO from 0.96 to 4.91%, MnO from 0.022 to 0.26%, MgO from 0.29 to 2.63%, CaO from 0.48 to 3.52%. It is also characteristic that the content of Fe<sub>2</sub>O<sub>3</sub>, FeO, MnO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub> - the rocks are clearly divided into two groups. Particularly clearly, this separation is manifested in the content of Fe<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub>. Thus, by their content, the groups with Na<sub>2</sub>O content from 5.1 to 6.44% and 0.13-0.27%, K<sub>2</sub>O 0.65 - 4.58% and 3.85 - 9.33%, according to P<sub>2</sub>O<sub>5</sub> 0.05-0.206% and 0.41-4.5%.

In the TAS diagrams (Figure 2 a, b), most of the rocks of the tracheostomy line fall into the field of trachyandesites and trachytes; three analyzes are placed in the field of andesites. The alkali content of the rock refers to the K-Na series.

On the whole, in the diagram (Na<sub>2</sub>O + K<sub>2</sub>O) -SiO<sub>2</sub>, the main bimodal sub-alkaline trend of tephrits, trachibasalts - trachyandesites, trachytes and the Tolleitis differentiated trend of basalt-andesibasalt-andesite are confidently predicted. Noting these trends, it should be emphasized that in the petrochemical plan, the volcanoes of the Saralin Graben need to replenish the data.

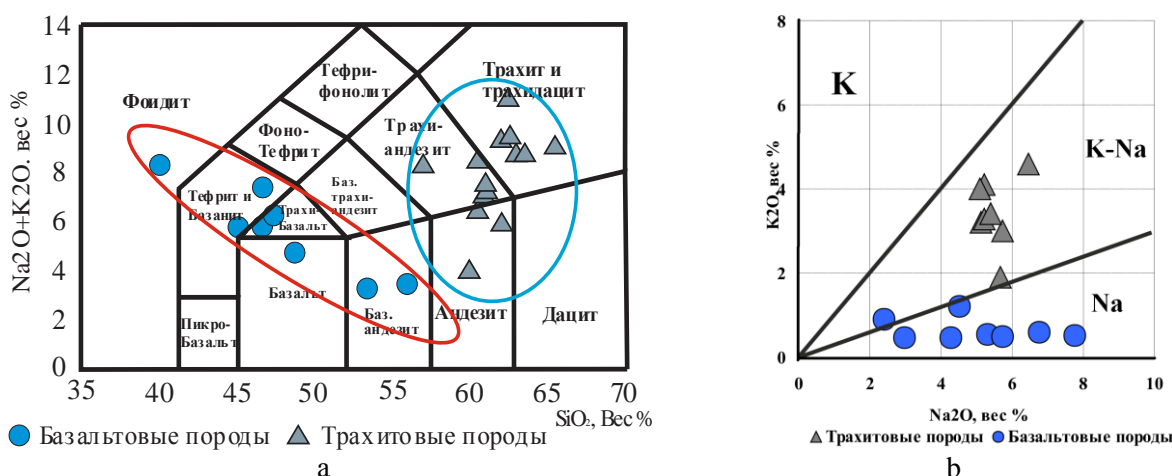


Figure 2, a, b. TAS diagrams (Na<sub>2</sub>O + K<sub>2</sub>O) -SiO<sub>2</sub> (a) and K<sub>2</sub>O-Na<sub>2</sub>O (b) for the Saralin Graben volcanoes (given by Le Maitre et al., 1989; Peccerillo and Naylor, 1976)

*Geochemical features* were identified on the basis of data from 36 analyzes performed at the Center for Collective Use "Geochemistry of Natural Systems" of TSU GGF by the ICP MS method.

The most striking geochemical features of the considered basanit, trachybasalt-trachyanthite, trachyte series of graben rocks are as follows. Basalts are enriched (g/t): Sc (3,2 – 31,8), Ti (1288,4 – 12565,4), V (28,5 – 240,8), Cr (4,0 – 128,4), Ni (3,1 – 50,4), Zn (2,3 – 1283,8), Sn (50,0 – 922,6), Y

(6,5 – 34,4), Zr (38,5 – 193,05); relatively low content are typical for Be, Co, Cu, Ga, Rb, Nb, Cs, Ba (3,2 – 238,05), P3O, Hf, Ta, slightly increased content Th (0,28 – 3,9) and U (0,17 – 2,9).

For trachyandesites, trachytes in high concentrations are contained (g/t): Be (0,25 – 7,8), Sc (0,7 – 38,4), Ti (761,8 – 13331,7), V (0,56 – 401,2), Cr (1,05 – 64,0), Co (0,78 – 45,5), Zn (14,6 – 147,7), Ga (4,6 – 23,3), Rb (5,0 – 148,3), Sn (13,3 – 895,8), Y (7,3 – 97,4), Zr (33,7 – 1019,0), Nb (4,1 – 60,8), Ba (57,5 – 973,3), rare earth elements, Hf (0,03 – 22,4), Th (0,9 – 17,4) и U (0,43 – 7,7).

The enrichment of the rocks of the basalt-trachyte series by some elements is end-to-end, for example, Ti, while others are abrupt, low for basalts and high for trachytes, for example, rare earth elements, and vice versa. As can be seen, elevated concentrations are characteristic mainly for lithophils, some siderophiles (Fe, Ni) and chalcophiles (Zn, Sn). The multi-element spiderdiagrams built based on analytical data, with the N-MORB, OIB, and IAB frames plotted on them, allow us to draw the following conclusions.

In the spider diagram of basalts (Figure 3, a), the distribution spectra of trace elements form their own trend, only partially coinciding with the OIB and IAB benchmarks. According to the configuration of broken curves, the geochemical spectra of basalts on the diagrams coincide most closely with OIB, but with the contents of trace elements from La to Lu reduced relative to this reference. The left part of the trace distribution spectra of the diagram indicates the enrichment of basalts with mobile (LILE) and moderately mobile (HFSE) coarse and high-charge elements, whose content is much closer to OIB basalts than the rest of the components.

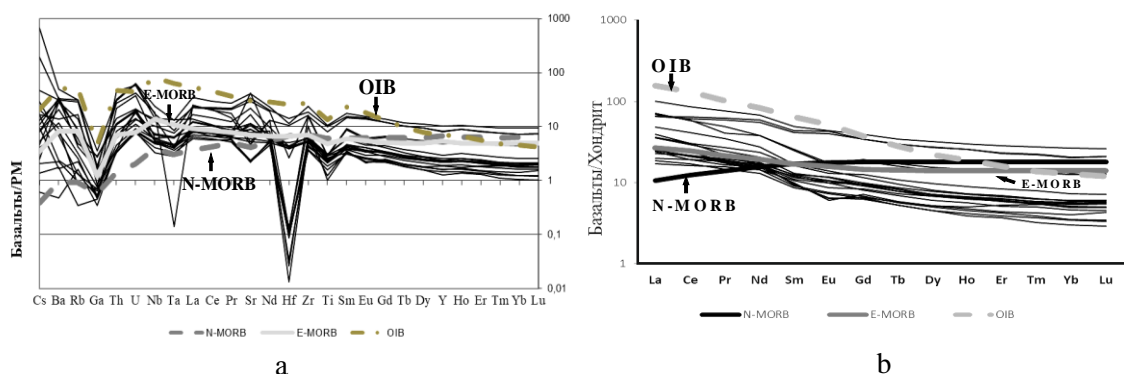


Figure 3, a, b. Multi-element (a) and rare-earth (b) spidergrams of basalts of the Saralin graben

For the rocks studied, with respect to the compositions of the primitive mantle, negative minima of the Ga, Ta, Hf and, to a lesser extent, Ti, contents are clearly manifested. Brightly developed peaks of positive concentric trace elements, relative to the reference frames used, are not observed in basalts.

On the diagram for trachytes, the distribution spectra of microelements are significantly more diverse than basaltic ones with the presence of a number of positive and negative peaks in the contents of most of them relative to basalts (Figure 4, a). However, in general, the conformance of the distribution spectra of microelements within the group of basalts and trachytes is obvious, which indicates their genetic relationship.

Concerning the reference lines of the diagram (Figure 4, a), the distribution spectra of trachytes micronutrients are still closer to OIB, while retaining individual geochemical features and are characterized by higher trace element contents for some trachyte species than their main group. The negative contents of microelements in trachytes characteristic for Ga, Ta, Sr, Hf, Ti, As well as positive peaks for Ba, Rb, Th, U, Nb, La, Zr, Sm и Er.

The individual trend of distribution of lanthanides in basalts relative to the N-MORB, OIB and IAB frames is more clearly visible on the distribution charts of rare-earth elements normalized by chondrite. The configuration of the distribution spectra of the red earth elements on the diagram (Figure 3, b) is conformal to the OIB frame. In this case, according to the content of rare-earth

elements, the spectra of basalts are divided into two subgroups. One of them (the smaller one) coincides in their content with the OIB, and the other (the larger one) contains about 10 times less rare-earth elements in smaller quantities. This geochemical feature of rock compositions is correlated with the presence of two main varieties among basalt-tephrites and trachybasalts. In trachybasalts, the Eu minimum is also weak.

The graph of the distribution of rare-earth elements in trachytes (Figure 4, b) is similar to basaltic, with the difference that the content of rare-earth elements in trachytes is about an order of magnitude higher than in basalts. Here, as in the rock basalts, the content of rare earth elements is divided into two subgroups, one of which is characterized by a low content of rare earth elements (subvolcanic trachytes), and the other is clearly elevated - extrusive eruptive trachytes.

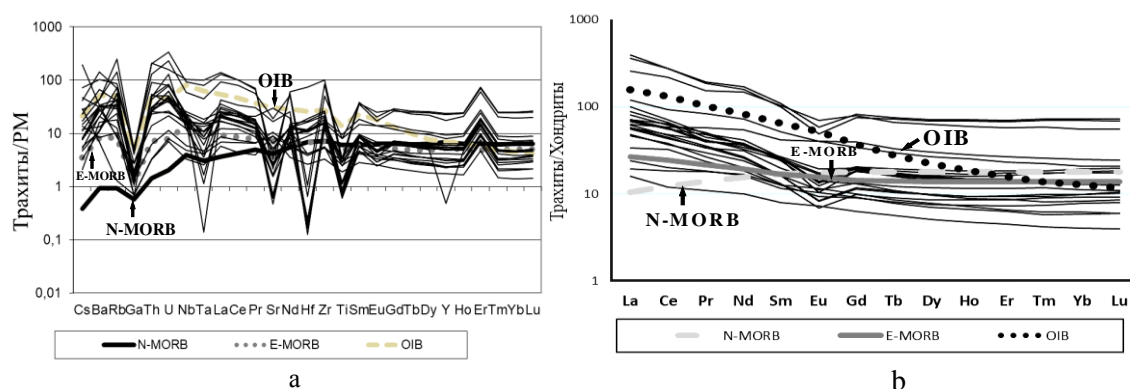


Figure 4, a, b. Multi-element (a) and rare-earth (b) spidergrams of trachytes of the Saralin graben

*The peculiarities of the geodynamic conditions for the formation of volcanic* make it possible in the first approximation to estimate the discriminant triple diagrams, with fields of figurative points of rock formations depicted on them, characterizing some kind of geodynamic etalons of the basalt volcanic manifestation (Figure 5 a, b, c).

In the La-Y-Nb diagram (Figure 5, a), the figurative points of volcanics fall into the field of continental basalts. In the Zr-Nb-Y diagram (Figure 5, b), the figurative points of volcanites are concentrated in the field of intraplate and island-arc basalts. And on the Th-Hf-Ta diagram (Figure 5, c), the points of the rock formations form an extended trail that captures the lower part of the field A characterizing N-MORB basalts, some of the points are located in field B (E-MORB basalts) and extend to the lower half of the field D corresponding to calc-alkaline basalts of island arcs. A significant part of the points is located on the side of the Th-Ta diagram and lies outside the indicator fields, but gravitating to the C field - intraplate alkaline basalts. This feature is primarily due to the enrichment of the rocks under consideration by radioactive elements, with parallel depletion of their Hf and Ta.

Thus, according to the totality of the data, it can be concluded that the basalts of the Saralin graben are formed in a continental setting close to the continental rifts, involving the formation of N-MORB, E-MORB, and the recycling of bark matter.

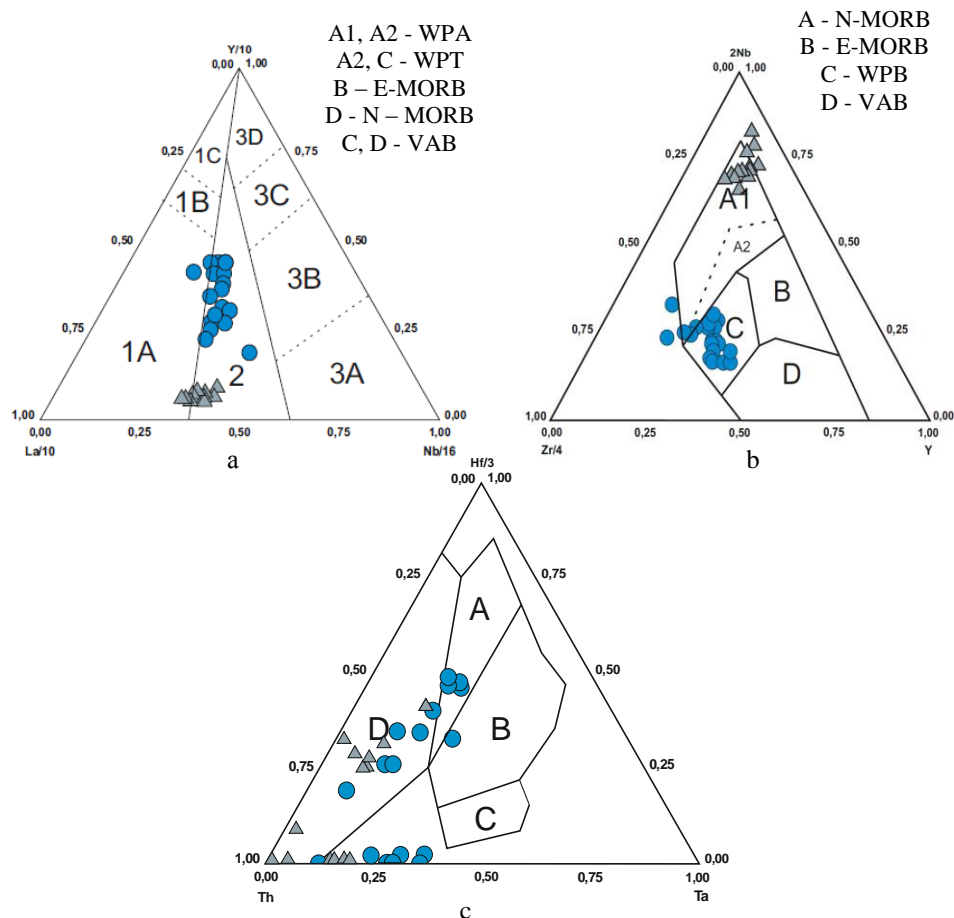


Figure 5 a, b, c. Diagrams of Th-Hf-Nb, Zr-Nb-Y, La-Y-Nb basalts and trachytes of the Saralin graben. The fields in the diagram, a - according to (Wood, 1980): 1 - island arc basalts (1A - calc-alkaline, 1B - overlapping area, 1C - tholeiites, 2 - continental basalts, 3 - ocean basalts, 3A - alkaline basalts of intercontinental rifts, 3B; 3C - enriched and slightly enriched E-MORB; 3D-N-MORB; b - according to (Meschede, 1986); c - according to (Cabanis, Lecolle, 1989)

The source materials of the initial magmas are estimated using the binary diagrams La/Y - Zr/Nb and Nb/Y - Zr/Y (Figure 6 a, b). According to the first diagram (Figure 6, a), the figurative points of the volcanic compositions of the series under investigation form a compact field in the immediate vicinity of the OIB and E-MORB frames, indicating that the source of the primary volcanic material was an enriched mantle converted under hot spot conditions or plume.

The diagram Nb/Y - Zr/Y (Figure 6, b) confirms and supplements the information of the first diagram. Here the figurative points of the rock formations form an elongated, but compact, trail along the dividing line of plume and extra-plume sources, confidently located in the field of plume formations. The trail begins near the relic of the primitive mantle and extends to the EM-2 and EM-1, reaching them.

Thus, a heterogeneous mantle, varying in composition from PM to EM-2-EM-1, with participation of recycling processes of the material of the consolidated crust formed during the Baikal and Salair tectogenesis, should be considered as a starting material of the basalt-trachyte series of volcanics of the Saralin graben.



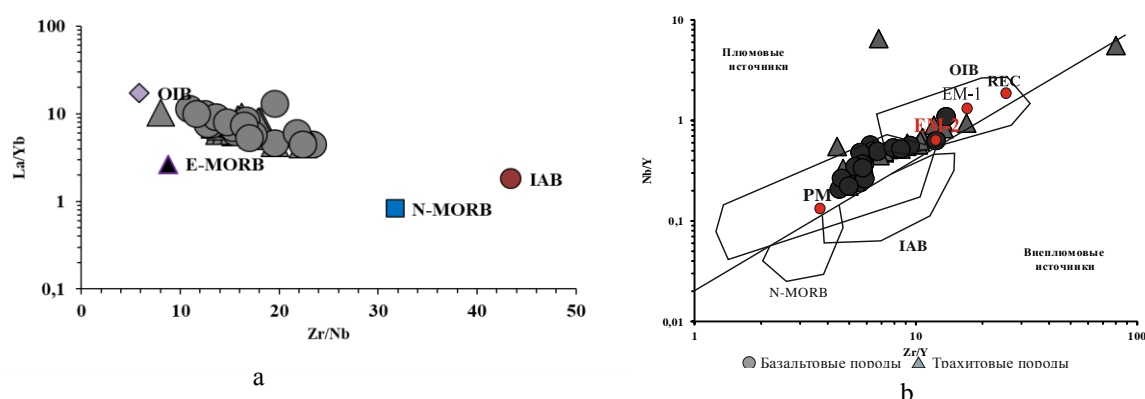


Figure 6, a, b. Geochemical indicators of sources of volcanic substances: a)  $La/Yb - Zr/Nb$ , b)  $Nb/Y - Zr/Y$

Mugs - basalt of various composition; triangles - rocks of the trachyte series; a -  $La/Yb - Zr/Nb$ ; b -  $Nb/Y - Zr/Y$ ; The points and fields of compositions of different types of basalts and igneous sources, according to [Sun, McDonough, 1989; Condi, 2005] N-MORB - mid-oceanic ridges (depleted), E-MORB - mid-ocean ridges (enriched with rare lithophilic elements), basalts of active continental margins and island arcs (IAB), intraplate continental and oceanic basalts (OIB); PM - primitive mantle, REC - recycled component, EM-1 - enriched mantle with high Nd/Sm, EM-2 - enriched mantle with high Rb/Sr

#### 4. Conclusions

(1) Formation of the Saralin graben occurred in the zone of the deep Balyksin-Saralinsky fault, which traces the western zone of the riftogenic Minusinsk trough. The situation in the fault zone was determined by two factors. Specific features of the early Devonian tectonic magmatic activation within the north-eastern part of the Kuznetsk Alatau, where the composite structures of the Kuznetsk-Alatau province were formed: volcanic-plutonic associations of grabens, alkaline-gabbroic plutons and dike belt-conditions of the formation within the "shoulder" of the paleorift. While in the complex structure of the Minusinsk trough there was a setting for the formation of the depression zone of the paleorift - deflection and dominant volcanism.

(2) In the situation of arbor formation and extension in Saralinsky prirazlomnom graben, as well as other grabens of the north of the Kuznetsk Alatau, sequences of motley-red-colored volcanogenic-terrigenous molasses were formed. The main features of the structure of the graben sections are: 1) the presence of a basaltic mass of molassoids (Ustkundustuylskaya, Krasnogorskaya strata); 2) formation of thick strata of volcanics corresponding to the composition of the Bazar thickness of the Goryachegor volcanic plateau; 3) and ending the incision of grabens of the ashpan volcanogenic-terrigenous stratum, for which the formation of extrusive-subvolcanic domes of trachyte composition is characteristic.

(3) According to petrographic and petrochemical data, the dominant basalt-trachyte series with the subordinate and fragmented development of nepheline rocks at the top of the sections is characteristic for the Saralinsky and other grabens of the region. According to the specified data, the volcanic series of the Saralin graben is represented by bimodal tephritis, trachybasalt-trachyandesite by the trachyte series, with the subordinate development of the thaleiitic trend of basalt-andesibasalt-andesite differentiates.

(4) The geochemical data cited in the work testify to the genetic unity of the studied series, its conspicuous similarity to the basalts of the oceanic islands (OIB), but with its inherent individual distinctive features. The series volcanics are specialized in a wide range of elements, especially Sc, Ti, Zn, Sn, Zr, Th, U, and possibly Mn and P.

(5) According to geological data and geochemical reference points, graben volcanites were formed under conditions of a consolidated continental crust that underwent destruction in the early Devonian under the influence of a mantle plume that caused continental rifting. Plume-tectonics led to the enrichment of primitive mantle and participation in the process of magma formation of the region's crust. Similar plume-mantle marks have volcanics of the southwestern part of the South Minusinsk depression [13], which closes with Balyksinsky graben.

(6) The explicit and rich mineragenic potential of the rocks of the studied basalt-trachyte series, especially in the part of Sc, Ti, Th, U and possibly P., is of particular interest. The rocks of the Saralin graben require further study.

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### References

- [1] Grinev O M 1990 *Evolution of alkali-gabbroic magmatism of Kuznetsk Alatau. The Author is abstract of the dissertation of the candidate a geol.-mineral. sciences* (Tomsk: Tomsk State University) p 18
- [2] Grinev O M 2007 *Rift systems of Siberia: the methodology of study, morphotectonics, mineralogy* (Tomsk: Tomsk State University) p 437
- [3] Grinev O M 2007 *Tuvinian-Minusinsko-Western-Siberian rift system: geology, morphotectonics, minerageny* (Tomsk: Tomsk State University) pp 185 – 193
- [4] Pokrovsky B G, Vrublevsky V V and Grinev O M 1991 *The role of host rocks in the formation of alkaline-gabbroic intrusions of the north of the Kuznetsk Alatau by isotopic data* (Izvestiya Rossiiskoi Akad. Series geological) pp 81 – 94
- [5] Pokrovsky B G, Andreeva E D, Vrublevsky V V and Grinev O M *Nature of the contamination of alkaline-gabbroic intrusions of the southern frame of the Siberian Platform according to the isotope of strontium and oxygen isotope* (Tomsk: Tomsk State University) pp 259 – 273
- [6] Vrublevsky V V, Gertner I F, Gutierrez-Alonso G, Hofman M, Grinev O M, Tishyn P A 2013 *U-Pb-isotope age of zircons in alkaline rocks of Kuznetsk Alatau* (Tomsk: Tomsk Polytechnic University) pp 147 – 151
- [7] Vrublevsky V V, Gertner I F, Gutierrez-Alonso G, Hofman M, Grinev O M, Tishyn P A 2014 *Isotope (U-Pb, Sm-Nd, Rb-Sr) geochronology of alkaline-basite plutons of Kuznetsk Alatau* (Tomsk: Tomsk State University) pp 1598 – 1614
- [8] Vrublevsky V V, Grinev O M, Isokh A E, Travin A V 2016 *Geochemistry, isotope (Nd-Sr-O) triad and  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  age of Paleozoic alkaline-mafic intrusions of the Kuznetsk Alatau (on the example of the Belogorsky pluton)* (Tomsk: Tomsk State University) pp 592 – 602
- [9] Mustafin V Z, Kryukov V G, Lykhina N S 1966 *The main features of the geological structure of the Talanovsk graben (North-West spurs of the Kuznetsk Alatau)* (Tomsk: Tomsk Polytechnic University) p 151
- [10] Kryukov V G, Mustafin V Z, Lykhina V S 1969 *The history of the formation of the Talanovsk graben (northern spurs of the Kuznetsk Alatau)* (Tomsk: Tomsk Polytechnic University) pp 80 – 85
- [11] Uvarov A N and Uvarova N M 2010 *Petrotypes of the base-Ashpan trachytephrite-trachybasalt complex* (Novosibirsk: SSRIGGaMC) p 180
- [12] Grinev O M 1994 *On the mechanism of formation of graben structures in the northern part of the Kuznetsk Alatau* (Tomsk: Tomsk State University) pp 237 – 259
- [13] Grinev O M, Kotelnikov A D, Kaplun M V and Grinev R O 2016 *Plum-riftogenic Early Devonian Volcanic Association of Tashtypsky District Minusinsk*