УДК 552.323.6+550.42

DOI 10.21440/2307-2091-2017-1-14-18

ВЕЩЕСТВЕННЫЙ СОСТАВ БАЗАЛЬТОВ ИЗ ДОЮРСКОГО ОСНОВАНИЯ ЗАПАДНОЙ СИБИРИ (ЗАПАДНО-ТАРКОСАЛИНСКАЯ ПЛОЩАДЬ, ЯНАО)

В. С. Пономарев, Ю. В. Ерохин, К. С. Иванов

Composition of basalts from the pre-Jurassic basement of Western Siberia (West-Tarkosalinskaya area, Yamalo-Nenets autonomous district)

V. S. Ponomarev, Yu. V. Erokhin, K. S. Ivanov

This paper presents the first results of study of mineralogical, petrological and geochemical composition of volcanites from pre-Jurassic basement of the West-Siberian megabasin near the West-Tarkosalinsk oil and gas deposit. West-Tarkosalinsk area is located on the territory of Purovsky region of Yamalo-Nenets Autonomous District of Tyumen region. Gubkinsky and Tarko-Sale are the towns nearest to the deposit. Volcanites of the well West-Tarkosalinsk 905 from the depth of 4362-4397 m have a small amount of dolerites present in the upper part of the section, which change to porphyritic basalts with depth. By chemical composition, the studied volcanites belong to moderate- and high calc-alkaline basalts and andesibasalts. The rocks have undergone post-magmatic transformation (formation of albite, replacement of volcanic glass with chlorite, development of the secondary carbonate, prehnite, titanite and pumpellyite) under the conditions of prehnite-pumpellyite facies (bottoms of the greenschist facies of metamorphism). Volcanites contain high concentration of (g / t) Ti (up to 8673), V (up to 275), Mn (up to 1304), Zn (up to 95), Sr (up to 231), Zr (up to 162), Ba (up to 397), Ce (up to 41). The content of rare earth elements in rocks is about 59–116 g / t. The trend of distribution of rare earth elements normalized to chondrite for basalts is characterized by a predominance of light lanthanide elements over heavy lanthanide elements and either a lack of (W-Tar 905 / 4396.56), or the presence of a weak negative Eu anomaly. E-MORB basalts have a similar distribution of rare earth elements, but at a lower content of light lanthanide elements. According to petrological and geochemical characteristics, the studied volcanites are similar to the basalts of Koltogorsky-Urengoysky rift of the West-Siberian megabasin.

Keywords: mineralogy; geochemistry; basalts; pre-Jurassic basement; West-Tarkosalinsk deposit; Western Siberia.

В работе приводятся первые результаты исследования минералогического и петролого-геохимического состава вулканитов из доюрского основания Западно-Сибирского мегабассейна в районе Западно-Таркосалинского нефтегазового месторождения. Западно-Таркосалинская площадь расположена на территории Пуровского района Ямало-Ненецкого автономного округа Тюменской области. Ближайшими пунктами к месторождению являются города Губкинский и Тарко-Сале. Вулканиты из скважины Западно-Таркосалинская 905, вскрытые на глубине 4362–4397 м, характеризуются наличием небольшого количества долеритов в верхней части разреза, которые с глубиной меняются на порфировые базальты. По химическому составу исследуемые вулканиты относятся к умеренно- и высоко-калиевым известково-щелочным базальтам и андезибазальтам. Породы подверглись постмагматическому преобразованию (образование альбита, замещение вулканического стекла хлоритом, развитие вторичного карбоната, пренита, пумпеллиита и титанита) в условиях пренит-пумпеллиитовой фации (низов зеленосланцевой фации метаморфизма). В вулканитах отмечается повышенная концентрация (в г/т) Ti (до 8673), V (до 275), Mn (до 1304), Zn (до 95), Sr (до 231), Zr (до 162), Ba (до 397), Ce (до 41). Содержание редкоземельных элементов в породах 59–116 г/т. Тренд распределения редкоземельных элементов, нормированных на хондрит для базальтов, характеризуется преобладанием легких лантаноидов над тяжелыми и либо отсутствием (W-Тар 905/4396,56), либо наличием слабой отрицательной европиевой аномалии. Близкое распределение редкоземельных элементов, но при меньшем содержании легких лантаноидов имеют базальты E-MORB. По петролого-геохимическим характеристикам исследуемые вулканиты имеют сходство с базальтами Колтогорско-Уренгойского рифта Западно-Сибирского мегабассейна.

Ключевые слова: минералогия; геохимия; базальты; доюрский фундамент; Западно-Таркосалинское месторождение; Западная Сибирь.

Study of the basalt complexes of pre-Jurassic basement of the West Siberian megabasin is a subject of a large number of publications [1, 2, 3–7, 8–10, 11–15, 16 and many others].

Triassic period is important for the understanding of the main events in the history of the formation of the West Siberian megabasin. By this time ended Late Paleozoic folding and granitization that consolidated Paleozoic complexes of the vast territory of the future megabasin. According to the ideas of the majority of Western Siberia researchers, during the Triassic, compression changed to sublatitudinal stretching accompanied by the emergence of system rifts or grabens [12, 17, 18 etc.]. According to widely known ideas of N. L. Dobretsov [19 et al.], on the territory of both Eastern and Western Siberia existed Late Permian-Triassic superplume, occurring mainly in the form of basaltic magmatism. Some researchers [20 and others] Justified the idea that the Early Triassic basalts of Western Siberia compose a single geodynamic type associated with the main folding in related orogens and called it synorogenic. Tholeiitic magmatism of Middle and Late Triassic, according to these authors, was accompanied by a powerful arched uplift of the region-cataplatform arch-genesis. Then, as they say, there was a period of regional subsidence. V. F. Podurushin [21 etc.] proposed sufficiently complex constructions of the mantle pulses propagating like a geodynamic wave, leading to the emergence of structural parageneses of shift, as the cause of the formation of the graben system of Western Siberia.

The variety of ideas about the nature of the geodynamic Triassic formations of the Western Siberia shows that we cannot consider this problem fully studied. Apparently, the main reason for the ambiguous interpretation of the nature of the Triassic complexes of is that they are generally overlain by a thick sedimentary cover of Jurassic and younger sediments and uncovered by a limited number of boreholes, mostly drilled only to the upper edge of the Triassic formations. Therefore, due to the limited material for research it is important to study comprehensively all available core samples from the boreholes for the understanding of the geological structure of the pre-Jurassic basement of the West Siberian megabasin. Detailed analysis of these samples can significantly expand the base of reliable data on the deep structure and development of the territory.

In this paper, we present the first results of mineralogical and petrological-geochemical composition of the volcanites from pre-Jurassic basement of the West Siberian megabasin near West-Tarkosalinsk oil and gas deposit. West-Tarkosalinskaya area is located on the territory of Purovsk region of Yamalo-Nenets Autonomous District of the Tyumen region. The nearest towns to the deposit are Gubkinskiy and Tarko-Sale.

Borehole West-Tarkosalinskaya 905 find basalts and dolerites at a depth of 4362–4397 m. Above and below (prior to borehole bottom at 4507 m) the thickness of the basalts were uncovered volcanic tuffs of basic composition. Dolerite in small quantities appears only in the upper part of the section, further replaced by the porphyritic basalts.

Petrography and mineralogy of volcanites

Dolerites have porphyric, dolerite structure, massive texture. Mineral composition: plagioclase ≈ 45%; clinopyroxene ≈ 20%; carbonate ≈ 13%; chlorite ≈ 20%; titanite ≈ 1%; ore mineral ≈ 1%. Porphyry phenocrysts in the rocks occupy about 15% of the total volume and consist mainly of clinopyroxene with augite composition, with traces of chloritization through cleavage cracks. Phenocrysts size varies from 0.5 to 1 cm by elongation. The rocks have undergone intensive secondary changes.

Basalts have porphyric structure, massive texture. The rocks have undergone secondary changes in the form of chloritization and carbonation. The mineral composition of basalts: plagioclase ≈ 50 %; chlorite ≈ 20%; clinopyroxene ≈ 10%; carbonate ≈ 5%; prehnite ≈ 5 %; pumpellyite ≈ 5%; titanite (replaces titanomagnetite) ≈ 3–4%; apatite ≈ 1%; ore minerals (chalcopyrite disseminations up to 1%).

Phenocrysts in the rock occupy about 10% of volume and consist mainly of plagioclase and clinopyroxene (Fig. 1). Clinopyroxene phenocrysts size varies from 2.5 to 7 mm in elongation, and plagioclase – up to 2 mm. The basis of rock is presented by elongated plagioclase laths and clinopyroxene grains in chlorite aggregates. The size of the cross sections of plagioclase grains in the base does not exceed 0.75 mm in elongation; sectional shape is elongated-tabular. Plagioclase microliths make up 60 % of the baseline volume, completely immersed in chloritized volcanic glass. The grains of clinopyroxene in the basis are idiomorphic relating to plagioclase.

Figure 1. Basalt with grains of plagioclase and clinopyroxene. Photo of the cone of West-Tarkosalinskaya 905/4370.4. With the analyzer. Zoom 25x.

Clinopyroxene is transparent; it has a brownish color, with no expressed pleochroism. Frequently, in clinopyroxene grains there are simple twins to [010]. According to the microprobe analysis pyroxene refers to ferriferous augite (see Table 1, no. 1–9). The mineral contains significant amounts of impurities of aluminum (Al_2O_3 up to 2.5 wt. %), titanium (TiO_2 up to 0.8 wt. %), traces of sodium (Na_2O up to 0.3 wt. %) and manganese (MnO up to 0.5 wt. %). Clinopyroxene grains are shattered with many cracks, and at the edges are replaced by green aggregate of secondary minerals (with a predominance of chlorite and constant presence of pumpellyite and prehnite).

The plagioclase is transparent, sometimes has a polysynthetic twinning by albite law. By the composition, all the grains belong to the pure albite (see Table 1, no. 10–15), only one grain had an admixture of up to 1.1 wt. % CaO (probably remains of the primary plagioclase). Among other impurities, mineral contains only iron, characteristic of plagioclases from volcanites.

Titanite in basalt is presented by complete pseudomorphisms by skeletal crystals of primary titanomagnetite, and relicts of the ore mineral had not survived. Pseudomorphisms size up to 1 mm. The mineral has dark nacreous colors with the analyzer and has a brown color without the analyzer. No pleochroism. According to microprobe analysis one can quite confidently determine it as titanite (see Table 1, no. 16–20), even though it contains significant impurities of aluminum (Al_2O_3 up to 4.8 wt. %) and iron (FeO up to 2.9 wt. %). Since iron in the mineral can enter only in position of titanium (together with alumina), it most likely is included as a trivalent element.

Minerals of the basis came under intense change. Volcanic glass in the rock and boundary of the grains of clinopyroxene replaced by aggregates of chlorite. Without the analyzer, chlorite has a greenish color

Table 1. The chemical composition of minerals (in wt. %) of basalt (borehole W-Tar 905, depth 4370.4 m).

№	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
Clinopyroxene											
1	51,22	0,82	2,54	0,02	11,46	0,28	13,51	19,13	0,26	–	99,24
2	52,00	0,65	1,74	0,01	12,04	0,31	13,27	18,89	0,27	0,01	99,20
3	51,62	0,71	2,17	0,02	11,08	0,36	13,83	19,45	0,28	–	99,53
4	51,50	0,70	1,38	–	13,37	0,45	12,74	18,68	0,23	0,01	99,06
5	51,60	0,77	2,22	0,14	12,59	0,37	12,27	18,87	0,25	–	99,08
6	51,23	0,80	1,85	–	13,40	0,44	11,97	18,56	0,29	–	98,54
7	52,16	0,68	1,57	–	12,67	0,33	12,96	18,96	0,28	–	99,61
8	51,21	0,82	2,35	0,04	12,78	0,44	13,73	18,16	0,30	–	99,83
9	51,56	0,72	1,69	0,07	12,83	0,30	13,08	19,03	0,29	0,01	99,57
Plagioclase											
10	68,38	–	19,60	0,04	0,14	–	–	0,31	11,83	0,02	100,32
11	67,32	–	19,73	0,01	0,38	0,03	0,04	1,13	11,15	0,02	99,81
12	68,08	0,05	18,21	0,07	0,15	0,07	0,09	0,27	12,17	0,02	99,18
13	68,40	0,02	18,52	0,23	0,20	–	0,04	0,10	11,61	0,03	99,15
14	68,10	–	19,21	0,36	0,08	0,06	0,02	0,16	11,43	0,01	99,42
15	68,79	–	19,34	0,10	0,12	–	–	0,17	11,73	0,09	100,34
Titanite											
16	29,61	36,37	2,47	0,24	2,01	–	0,01	28,40	0,03	0,01	99,15
17	30,29	34,98	2,64	0,06	2,63	–	0,01	28,81	0,02	0,01	99,45
18	30,28	34,98	2,44	0,06	2,65	–	0,02	28,58	0,01	0,01	99,03
19	29,84	35,22	4,76	0,01	1,26	0,02	–	28,69	0,06	0,07	99,93
20	30,89	33,41	4,93	0,66	1,43	–	0,08	27,94	0,06	0,01	99,41
Chlorite											
21	28,75	0,02	15,47	0,36	29,10	0,61	12,02	0,32	0,01	0,01	86,67
22	28,58	–	15,05	0,25	28,72	0,65	11,46	0,32	0,02	0,01	85,06
23	28,97	0,02	15,81	0,86	28,75	0,51	11,70	0,39	0,04	0,02	87,07
24	27,86	–	15,43	0,34	30,50	0,63	11,31	0,27	0,02	–	86,36
Vermiculite											
25	46,43	0,06	15,09	0,11	9,86	0,19	9,50	0,28	0,10	8,68	90,30
Ferrypumpellyite											
26	39,03	0,04	20,16	0,20	10,59	0,19	3,42	18,29	0,02	0,02	91,97
Prehnite											
27	43,30	0,03	22,50	0,21	2,28	0,10	0,50	26,96	0,03	–	95,91
28	43,09	0,03	22,80	0,06	1,97	0,03	0,45	27,48	0,02	0,02	95,95

Note: the analysis are conducted on the microanalyzer CAMECA SX 100 (IGG UB RAS, analyst V. V. Khiller).

Table 2. Chemistry (wt. %) and trace element (g/t) composition of volcanites (borehole W-Tar 905).

Elements	1	2	3	Elements	1	2	3
SiO_2	44,99	50,03	47,75	Mo	0,17	0,26	1,38
TiO_2	1,66	0,75	0,89	Ag	0,31	0,13	0,18
Al_2O_3	15,35	15,86	15,98	Cd	0,02	0,02	0,08
Fe_2O_3	9,55	4,77	6,14	Sn	1,74	0,79	0,98
P_2O_5	0,36	0,17	0,18	Sb	0,20	0,18	0,10
MnO	0,21	0,18	0,18	Te	0,04	0,01	0,01
FeO	5,90	4,60	3,90	Cs	0,09	0,12	0,13
MgO	6,29	8,69	8,82	Ba	135,49	354,82	396,66
CaO	7,67	6,52	7,04	La	18,96	8,93	11,37
Na_2O	2,38	3,28	3,03	Ce	40,55	19,93	24,40
K_2O	0,99	0,98	1,25	Pr	5,14	2,59	3,18
Others	4,20	3,90	4,40	Nd	21,51	11,58	13,18
Total	99,55	99,73	99,56	Sm	4,99	2,63	3,14
Li	6,07	10,06	8,24	Eu	1,51	0,80	1,05
Be	0,88	0,35	0,77	Gd	5,60	3,10	3,49
Sc	32,03	36,47	30,78	Tb	0,89	0,48	0,56
Ti	8672,96	3891,44	4434,02	Dy	6,07	3,27	3,89
V	274,57	171,47	190,41	Ho	1,35	0,74	0,84
Cr	2,81	229,27	141,34	Er	4,09	2,25	2,60
Mn	1303,57	1081,08	1056,75	Tm	0,59	0,32	0,38
Co	30,90	31,27	29,00	Yb	3,95	2,10	2,50
Ni	13,38	61,72	61,97	Lu	0,63	0,32	0,39
Cu	79,13	45,33	55,16	Hf	4,19	2,05	2,41
Zn	94,74	50,68	58,55	Ta	0,83	0,37	0,50
Ga	18,14	9,82	12,85	W	0,81	0,35	0,58
Ge	1,55	0,98	1,15	Nb	10,15	4,87	5,81
Rb	16,83	26,40	34,31	Pb	5,90	1,41	3,39
Sr	84,22	231,20	189,04	Bi	0,03	0,02	0,03
Y	34,75	20,01	21,64	Th	3,85	1,76	2,24
Zr	161,89	76,67	93,52	U	3,25	1,51	1,87

Note: analyses were carried out on the wave spectrometer XRF-1800 of SHIMADZU company and the mass-spectrometer ELAN 9000 (IGG UB RAS, FHMI laboratory). no. 1 – W-Tar 905/4370.4 basalt; 2 – W-Tar 905/4386.6 andesite-basalt; 3 – W-Tar 905/4396.56 basalt.

with well-manifested pleochroism from dark green (by Ng) to greenish-yellow (by Np). With the analyzer, it has an abnormal yellowish-green color. According to microprobe analysis chlorite it is characterized by stable chemical composition (see Table 1, no. 21–24) and refers to the magnesian chamosite with an admixture of MgO up to 12 wt. %. Other impurities of the chlorite are the traces of calcium, manganese and chromium. Chlorite aggregates constantly contain accumulations of prehnite and pumpellyite.

In the peripheral parts of chlorite clusters (particularly in the places of substitution of volcanic glass) we observed small (10–15 microns) foliated mica individuals. They pleochroate from dark brown to yellowish. According to microprobe analysis we quite confidently define it as hydrated biotite and vermiculite (see Table 1, no. 25). Apparently, during the replacement of volcanic glass with chlorite, potassium, sprayed within, concentrated in the form of an independent mineral.

Pumpellyite tends to clusters of chlorite and visually does not differ from it, also composes of massive dense aggregates of greenish color. We diagnosed it only by the results of microprobe analysis and quite confidently defined it as ferrypumpellyite (see Table 1, no. 26). The mineral contains up to 7.5 % water and most of the iron is composed of oxide form, thus, amount provided in the table seems lowered.

Prehnite creates its own cluster among the chlorite-pumpellyite aggregate, size of up to 50–100 microns, white. In the thin section it is pure, translucent, whitish, contains no other minerals. The microprobe analysis quite confidently defines it as the prehnite (see Table 1, no. 27–28), even though it contains a significant admixture iron (FeO up to 2.3 wt. %). Since iron in this mineral may be included only in the position of aluminum, then most likely it comes as a trivalent element.

Accessory apatite creates small prisms, up to 20–30 microns in length, transparent and without inclusions. Apatite grains are immersed in basis and rarely form inclusions in individuals of augite and plagioclase.

On the plagioclase and the basis carbonate sometimes develops, which essentially is dolomite. The basis always contains small patches of fine grains of sulfides, sizes of up to 50 microns. According to the EDS-consoles all sulfides correspond to chalcopyrite and do not contain any impurities. Dolerites and basalts undergone intensive chloritization and carbonation in a prehnite-pumpellyite facies, i. e., in the lower greenschist facies of metamorphism.

The chemical and microelement composition of volcanites

In the basalts from the borehole West-Tarkosalinskaya 905 one can observe significant secondary changes, chloritization and carbonation, as evidenced by the high content of loss on ignition (at the level of 4–4.5%). Basalts contain high amounts of alumina (Al_2O_3 15.35–15.98 wt. %). By the content of K_2O + Na_2O, (3.37–4.28 wt. %) studied basalts belong to the rocks of normal alkalinity. At the same time, by the amount of K_2O (0.98–1.25 wt. %) studied basalts are medium and high potassic (Table 2). On the classification diagram TAS [22], two samples of basalt (W-Tar 905/4370.4 and W-Tar 905/4396.56) from the borehole West-Tarkosalinskaya 905 fall to the field of basalts with normal alkalinity (Fig. 2). One sample (W-Tar 905/4386.6) fell in the field of andesite-basalts. The volcanites have an increased concentration (g/t) of: Ti (up to 8673), V (up to 275), Mn (up to 1304), Zn (up to 95), Sr (up to 231), Zr (up to 162), Ba (up to 397), and Ce (up to 41). The content of rare earth elements in rocks is 59-116 g/t (Table 2). Trend of distribution of rare earth elements normalized to chondrite for basalts (Fig. 3) is characterized by a predominance of LREE over HREE and either lack (W-Tar 905 / 4396.56), or the presence of a weak negative Eu anomaly. E-MORB basalts have a similar distribution of rare earth elements, but at a lower content of LREE (primitive basalts enriched with elements of impurities).

By the nature of distribution of rare, scattered and rare earth elements basalts from the borehole West-Tarkosalinskaya 905 are close to the Permian-Triassic volcanites of Koltogorsk-Urengoy rift of the Western Siberia [11] (relatively closely located to the borehole SG-6, the distance between them is about 130 km, and a borehole Nikol'skaya 1 in the southern part of the said rift) and differ from basalts we previously studied for the Danilovskiy graben of Shaim region (our data) of the Western Siberia (basalts of Symoryahsk area) by lower contents of LREE and REE distribution trend.

Using discriminatory charts for reconstructing the geodynamic environments of basalts formation is widely spread. Pictures 4–6 show the discriminatory diagrams for basalts of West-Tarkosalinsk area. On the diagram Th–Zr/117–Nb/16 (Fig. 4) studied basalts and andesite-basalts fall into the field of island arc basalts. On the discriminatory diagram Th–Hf/3–Ta (Fig. 5) volcanites fall into the field of calc-alkaline volcanic arc basalts. The diagram Zr–Ti/100–Y_3 (Fig. 6) samples fall within the border area of calc-alkaline basalts and basalts of mid-ocean ridges.

Thus, the volcanite s from the borehole West-Tarkosalinskaya 905 uncovered at a depth of 4362–4397 m are characterized by the presence of a small amount of dolerites in the upper part of the section, which are replaced by the porphyritic andesite-basalts and basalts in the lower part of the section. The chemical composition of the studied volcanites belongs to the moderate- and high calc-alkaline basalts and andesite-basalts.

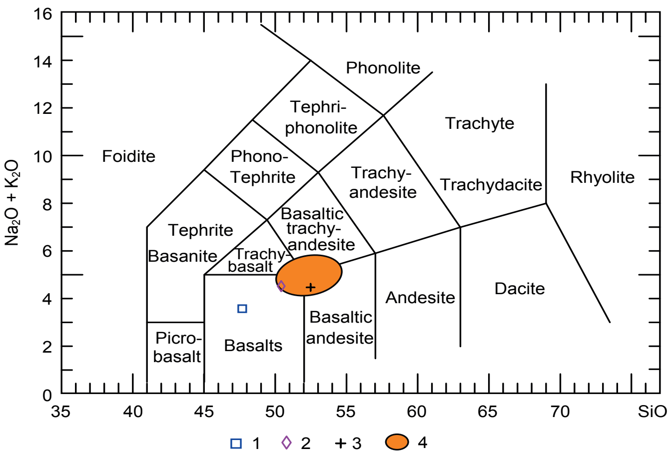

Figure 2. The classification diagram TAS [22] for basalts from the borehole West-Tarkosalinskaya 905. 1 – W-Tar 905/4370.4; 2 – W-Tar 905/4396.56; 3 – W-Tar 905/4386.6; 4 – Field of Triassic basalts of Symoryahsk area of Danilovskiy graben of Shaim district of Western Siberia.

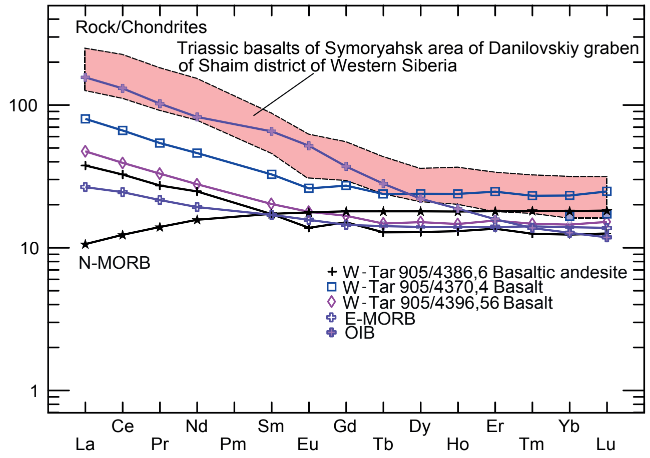

Figure 3. Distribution diagram of rare earth elements normalized to chondrite [24], in the volcanites from the borehole West-Tarkosalinskaya 905.

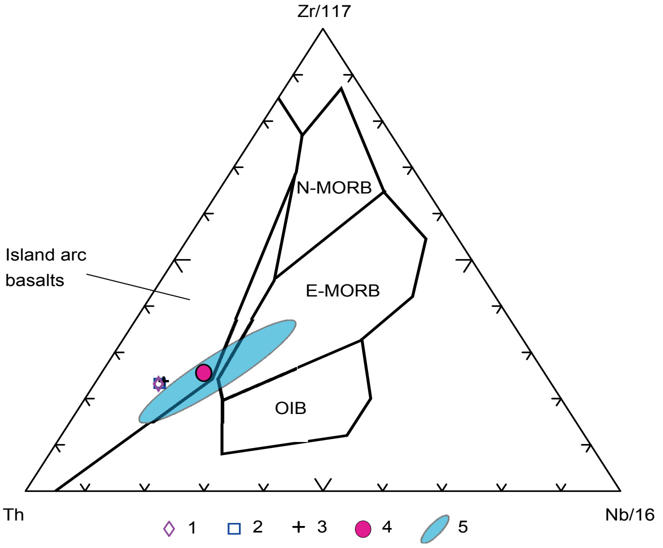

Figure 4. Discriminatory diagram Th–Zr/117–Nb/16 [25] for volcanites from borehole West-Tarkosalinskaya 905. Here and below in Figures 4–6. 1 – W-Tar 905/4396.56 basalt; 2 – W-Tar 905/4370.4 basalt; 3 – W-Tar 905/4386.6 andesite-basalt; 4 – field of volcanites of Symoryahsk area of Shaim region of the Western Siberia; 5 – basalts from Tyumen borehole SG-6 [11]; N-MORB – basalts from mid-ocean ridges, E-MORB – basalts enriched with impurities, primitive basalts, OIB – basalts of oceanic islands.

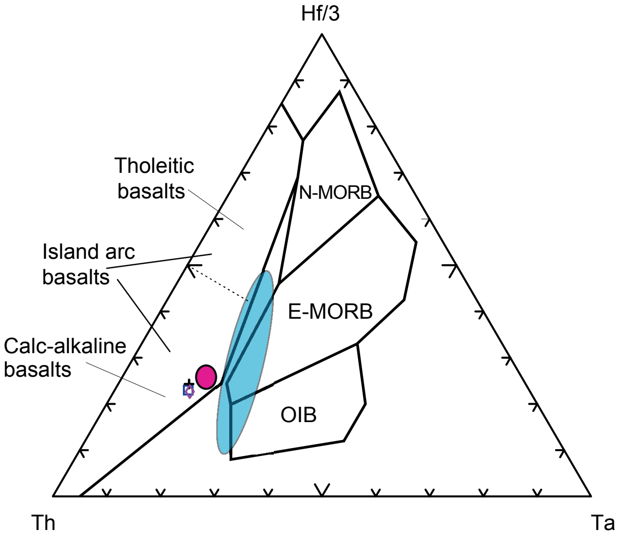

Figure 5. Discriminatory diagram Th–Hf/3–Ta [25] for basalts and andesite-basalts from the borehole West Tarkosalinsk 905.

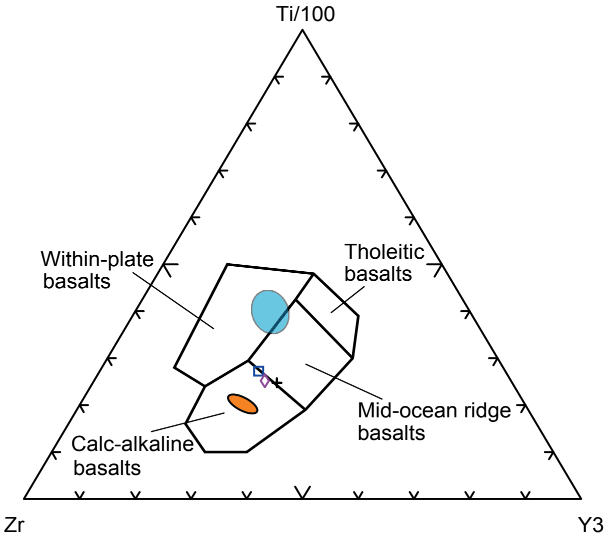

Figure 6. Discriminatory diagram of Zr–Ti/100–Y_3 [23] for basalts and andesite-basalts from the borehole West Tarkosalinsk 905.

The rocks have features of island-arc volcanites, as borehole as features characteristic of basalts enriched with elements of impurities (E-MORB). The study of rock mineralogy revealed that rocks have undergone post-magmatic transformation (formation of albite, volcanic glass replacement with chlorite, development of the secondary carbonate, prehnite, titanite and pumpellyite) under prehnite-pumpellyite facies (bottom greenschist metamorphic facies).

According to petrological and geochemical characteristics, studied volcanites are similar to basalts from adjacent Tyumen super-deep borehole, where along with tholeiitic basalts one can observe medium- and high-K calc-alkaline basalts differences that researchers attribute to the northern part of the Koltogorsk-Urengoy rift of Western Siberia [11 etc.].

This work was supported by the Russian Science Foundation (№ 16-17-10201).

REFERENCES

1. Al'mukhamedov A. I., Medvedev A. Ya., Kirda N. P., Baturina T. P. 1998, *Triasovyi vulkanogennyy kompleks Zapadnoy Sibiri* [Triassic volcanic complex of the Western Siberia]. *Doklady Akademii Nauk* [Doklady Earth Sciences], vol. 362, no. 3, pp. 372–377.

2. Bochkarev V. S. 2001, *Vulkanogennye obrazovaniya triasa Zapadnoy Sibiri* [The volcanic formation of the Triassic of West Siberia]. *Trias Zapadnoy Sibiri* [Triassic of the Western Siberia], Novosibirsk, pp. 70–79.

3. Dobretsov N. L., Kirdyashkin A. G., Kirdyashkin A. A. 2001, *Glubinnaya geodinamika* [Deep geodynamics], Novosibirsk, 409 p.

4. Ivanov K. P., Ivanov K. S., Fedorov Yu. N. 2007, *Geokhimiya triasovykh vulkanitov Zapadno-Sibirskoy plity (na primere tyrinskoyi serii)* [Geochemistry of the Triassic volcanic rocks of the West Siberian plate (based on the example of the Turin series)]. *Geodinamika, magmatizm, metamorfizm i rudoobrazovanie* [Geodynamics, magmatism, metamorphism and mineralization], Ekaterinburg, pp. 766–790.

5. Ivanov K. S., Fedorov Yu. N., Ronkin Yu. L., Erokhin Yu. V. 2005, *Geokhronologicheskie issledovaniya fundamenta Zapadno-Sibirskogo neftegazonosnogo megabasseyna; itogi 50 let izucheniya* [Geochronological studies of basement of the West Siberian petroleum megabasin; the results of 50 years of study]. *Litosfera* [Litosphere], no. 3, pp. 117–135.

6. Zhuravlev E. G. 1986, *Trappovaya formatsiya Zapadno-Sibirskoy plity* [Trappean formation of the West Siberian Plate]. *Izvestiya AN SSSR. Seriya geol.* [Proceedings of the Academy of Sciences of the USSR. Series geology], no. 7, pp. 26–32.

7. Kremenetskiy A. A., Gladkikh V. S. 1997, *Nizkokalievye toleitovye bazal'ty – indikator evolyutsii paleogeodinamicheskikh obstanovok i prognoza uglevodorodnogo syr'ya (po dannym Tyumenskoy skvazhiny SG-6)* [Low-K tholeiitic basalts - the evolution indicator of paleogeodynamic environments of and prediction of hydrocarbon raw materials (according to data from the borehole Tyumen SG-6)]. *Geokhimiya* [Geochemistry International], no. 6, pp. 609–617.

8. Medvedev A. Ya., Al'mukhamedov A. I., Kirda N. P. 2003, *Geokhimiya permotriasovykh vulkanitov Zapadnoy Sibiri* [Geochemistry of Permian Triassic volcanic rocks of West Siberia]. *Geologiya i geofizika* [Russian Geology and Geophysics], vol. 44, no. 1–2, pp. 86–100.

9. Kontorovich A. E., Surkov V. S. et al. 1994, *Neftegazonosnye basseyny i regiony Sibiri* [Oil and gas basins and regions of Siberia], Novosibirsk, vol. 2, 201 p.

10. Ivanov K. S., Kormil'tsev V. V., Fedorov Yu. N. et al. 2003, *Osnovnye cherty stroeniya doyurskogo fundamenta Shaimskogo neftegazonosnogo raiona* [The main features of the structure of pre-Jurassic basement of the Shaim oil and gas district]. *Puti realizatsii neftegazovogo potentsiala KhMAO* [Ways of realization of oil and gas potential of KhMAO], Khanty-Mansiysk, vol. 1, pp. 102–113.

11. Saraev C. V., Baturina T. P., Ponomarchuk V. A., Travin A. V. 2009, *Permotriasovye vulkanity Koltogorsko-Urengoyskogo rifta Zapadno-Sibirskoy geosineklizy* [Permian-Triassic volcanites of Koltogorsk-Urengoy rift West Siberian geosyneclise]. *Geologiya i geofizika* [Russian Geology and Geophysics], vol. 50, no. 1, pp. 4–20.

12. Surkov V. S., Trofimuk A. A., Zhero O. G., Kontorovich A. E., Smirnov L. V. 1982, *Triasovaya riftovaya sistema Zapadno-Sibirskoy plity, ee vliyanie na strukturu i neftegazonosnost' platformennogo mezozoysko-kaynozoyskogo chekhla* [Triassic rift system of the West Siberian Plain, its impact on the structure and oil and gas platform Mesozoic and Cenozoic cover]. *Geologiya i geofizika* [Russian Geology and Geophysics], no. 8, pp. 3–15.

13. Simonov V. A., Klets A. G., Stupakov S. I. 2008, *Bazal'tovye kompleksy v fundamente Zapadno-Sibirskogo osadochnogo basseyna (dannye po skvazhine Mayzasskaya-1)* [Basalt complexes in the basement of the West Siberian sedimentary basin (data for the borehole Mayzasskaya-1)]. *Fundament, struktury obramleniya Zapadno-Sibirskogo osadochnogo basseyna i problemy neftegazonosnosti. Vserossiyskaya konferentsiya* [Structural framing structure of the West Siberian sedimentary basin, and oil and gas potential problems. All-Russian Conference]. Tyumen, pp. 197–201.

14. Simonov V. A., Klets A. G., Kovyazin S. V., Stupakov S. I., Travin A. V. 2010, *Fiziko-khimicheskie usloviya rannego plyumovogo magmatizma Zapadnoy Sibiri* [Physico-chemical conditions of the early plume magmatism of the Western Siberia]. *Geologiya i geofizika* [Russian Geology and Geophysics], vol. 51, no. 9, pp. 1277–1297.

15. Fedorov Yu. N. 2004, *Geologicheskoe stroenie i perspektivy neftegazonosnosti oblasti sochleneniya Pripolyarnogo Urala i Zapadno-Sibirskogo megabasseyna. Avtoref. dis... kand. geol.-mineral. nauk* [Geological structure and petroleum potential of the junction area of Polar Urals and West Siberian megabasin. Abstract of the dissertation of the candidate of geol.-mineral. sciences]. Ekaterinburg, 28 pp.

16. Reichow M. K, Saunders A. D., White R. V., Al'mukhamedov A. I., Medvedev A. Ya. 2005, Geochemistry and petrogenesis of basalts from the West Siberian Basin: an extension of the Permo-Triassic Siberian Traps, Russia. Lithos, vol. 79, pp. 425–452.

17. Kontorovich A. E., Nesterov I. I., Salmanov F. K. et al. 1975, *Geologiya nefti i gaza Zapadnoy Sibiri* [Petroleum Geology of the Western Siberia], Moscow, 679 p.

18. Kulikov P. K., Belousov A. P., Latypov A. A. 1972, *Zapadno-Sibirskaya triasovaya riftovaya sistema* [Western Siberian Triassic rift system]. *Geotektonika* [Geotectonics], no. 6, pp. 79–87.

19. Dobretsov N. L. 1997, *Permsko-triasovye magmatizm i osadkonakoplenie v Evrazii kak otrazhenie superplyuma* [Permian-Triassic magmatism and sedimentation in Eurasia as a reflection superplume]. *Doklady Akademii Nauk* [Doklady Earth Sciences], vol. 354, no. 2, pp. 220–223.

20. Bochkarev V. S., Brekhuntsov A. M., Deshchenya N. P. 2005, *Geodinamicheskie obstanovki formirovaniya Zapadno-Sibirskogo basseyna i ego neftegazonosnost'* [Geodynamic conditions of formation of the West Siberian basin and its petroleum potential]. *Tektonika zemnoy kory i mantii. Materialy XXXVIII Tektonicheskogo soveshchaniya* [Tectonics of the Earth's crust and mantle. Materials of XXXVIII Tectonic Conference], Moscow, vol. 1, pp. 71–74.

21. Podurushin V. F. 2004, *Geodinamicheskaya evolyutsiya fundamenta Zapadno-Sibirskoy plity v pozdneyi permi-triase* [Geodynamic evolution of the base-ment of the West Siberian plate in the late Permian–Triassic]. *Evolyutsiya tektonicheskikh protsessov v istorii Zemli* [Evolution of tectonic processes in the Earth's history], Novosibirsk, vol. 2, pp. 80–83.

22. Le Bas M. J., Le Maotre R. W., Streckeisen A., Zanettin B. 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram. Journal of Petrology, vol. 27, pp. 745–750.

23. Pearce J. A., Cann J. R. 1973, Tectonic setting of basic volcanic rocks determined using trace element analyses. Earth Planetary Science Letters, vol. 19, pp. 290–300.

24. Sun S. S., McDonough W. F. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Magmatism in Ocean Basins, London, pp. 313–345.

25. Wood D. A. 1980, The application of a Th–Hf–Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas on the British Tertiary Volcanic Province. Earth Planetary Science Letters, vol. 50, pp. 11–30.

Владимир Сергеевич Пономарев,
Юрий Викторович Ерохин,
Кирилл Святославич Иванов,
p123v@yandex.ru
Институт геологии и геохимии УрО РАН
Россия, Екатеринбург,
ул. Академика Вонсовского, 15

Vladimir Sergeevich Ponomarev,
Yuriy Viktorovich Erokhin,
Kirill Svyatoslavich Ivanov,
p123v@yandex.ru
Institute of Geology and Geochemistry of the Ural Branch
of the Russian Academy of Sciences
Ekaterinburg, Russia