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Geochemical proxies of the gryphon breccia of mud volcanoes in East Azerbaijan: regularities in the distribution of chemical elements and spatial characteristics of sedimentation

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ABSTRACT

The paper is devoted to the study of the patterns of distribution of major oxides and trace elements in the gryphon breccia of 12 active mud volcanoes located in various oil and gas regions (Absheron, Gobustan and Lower Kura) of Azerbaijan. Interpretations of the chemical elements found in gryphon breccia samples have allowed the composition of their source rocks, sedimentation conditions, and sedimentation areas to be determined.

Purpose. The main goal of the study is to conduct geochemical studies of gryphon breccias belonging to various oil and gas regions, determine spatial patterns, achieve their explanation, and at the same time determine the conditions for the deposition of mud sediments.

Methods. The chemical composition of mud volcanic breccia samples was analyzed using an “S8 TIGER Series 2” spectrometer and an “Agilent 7700 Series ICP-MS” mass spectrometer. Based on the results obtained, in addition to identifying patterns in the areas, modern approaches based on geochemical interpretation were used to explain them. The results on the genesis of breccias are consistent with the results of the published literature on the development of geodynamic and paleobasin conditions in the region.

Results. Samples with the lowest Si content are characteristic of the Lower Kura mud volcanoes, where the youngest (Quaternary) deposits are recorded. In samples from these mud volcanoes, relatively high contents of Mg and P are also noticeable. High contents of Ca are characteristic of volcanoes located near the Caspian Sea. These mud volcanoes are also rich in trace elements such as Li, Ga, Rb, Zr, Mo, Cs, Pr, Tl, Pb, Th, U and others, but depleted in Ni, Sr, Ba and etc.

Conclusions. Plagioclase-rich source rocks and oxygen-dominated paleobasin environments played a key role in the formation of breccia deposits belonging to the mud volcanoes of Azerbaijan. Geochemical proxies make it possible to link the paleobasin conditions of the formation of the gryphon breccia of the most mud volcanoes of South and Central Gobustan with the continental setting, especially in comparison with some volcanoes of the Lower Kura, as well as Gobustan and Absheron, located on the shores of the Caspian Sea and relatively close to it. The breccias of mud volcanoes located at a relatively large distance from the modern sea boundary and in the steepest northern part of the Lower Kura are associated with marine conditions, as are breccias of mud volcanoes located in the south of this tectonic zone (subjected to intense subsidence) and at a short distance from the Caspian Sea, may be due to geological factors.

Keywords*: gryphon breccia, chemical composition, regularity of distribution, conditions of sedimentation.*

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Introduction and research status. Geochemical study of the gryphon mud makes it possible to reveal some features of their nature, as well as to reconstruct their initial mineralogical composition and formation conditions. Back in the 1980s, the study of the geochemical properties of the gryphon muds of the volcanoes of Azerbaijan led to the fact that they were first used as a therapeutic drug [5]. In recent years, several studies have been carried out on the accessory mineralization of the gryphon breccia of volcanoes registered in East Azerbaijan [3], as well as on the study [1; 7; 8; 15; 16; 17; 18] of mud brought to the surface as a result of eruptions, according to geochemical and mineralogical proxies. Our analysis shows that, so far, the published literature has not assessed the regularity of the chemical composition of the gryphon breccia, which is characteristic of mud volcanoes located in different tectonic zones of Azerbaijan, belonging to different depths, as well as stratigraphic units. The areas of the spatial distribution of the deposits that formed them have not been studied enough. This study is based on monitoring East Azerbaijan mud volcanoes in 2017. Gryphon breccia samples were taken from active volcanoes of various tectonic zones, and their chemical composition was studied. The conducted studies made it possible to assess the distribution of chemical elements in tectonic zones and to determine the spatial conditions of the deposits that form gryphon breccias.

Material and methods. Samples were taken from 12 mud volcanoes located in Absheron, Gobustan and Lower Kura oil and gas regions (Fig. 1). The sampling of volcanic breccia was carried out in plastic containers, which were then transported to the chemical research laboratory of the "Center for Collective Use of Analytical Devices and Equipment" of the Institute of Geology and Geophysics of the Ministry of Science and Education of the Republic of Azerbaijan. After drying the samples in a muffle furnace at a temperature of 105 ℃, the analysis of major oxides was carried out on a Bruker "S8 TIGER Series 2", and trace elements on an "Agilent 7700 Series ICP-MS" mass spectrometer. When using ICP-MS, solid samples have been dissolved. The decomposition of the samples was carried out with a mixture of nitric, hydrofluoric and perchloric acids.

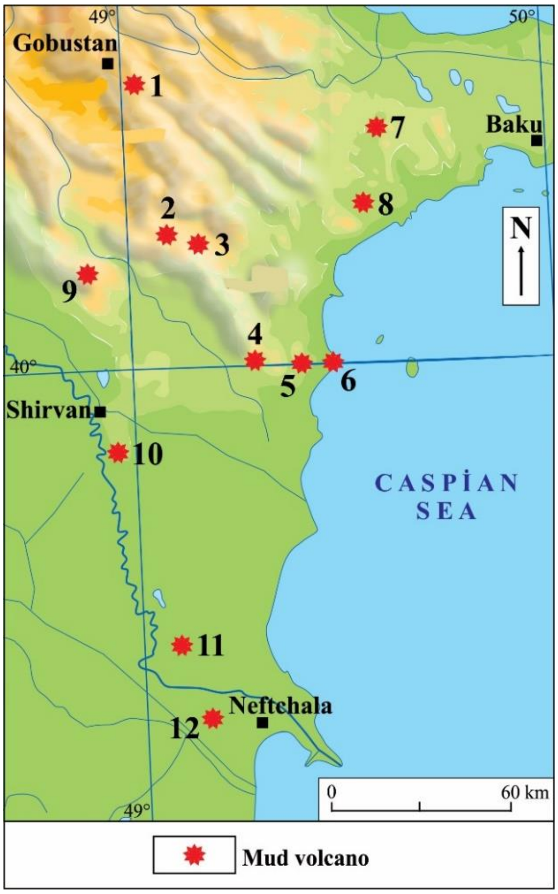

Fig. 1. Location map of the studied mud volcanoes of Eastern Azerbaijan. Mud volcanoes: 1 – Kichik Mereze, 2 – Shekikhan group, 3 – Aghdam group, 4 – Ayrantoken, 5 – Dashgil, 6 – Bahar, 7 – Deveboynu, 8 – Pilpile-Garadagh, 9 – Boyuk Heremi, 10 – Yandere, 11 – Durovdagh, 12 – Duzdagh

Geology and tectonics: a general overview. Mud volcanoes Kichik Mereze located in Central Gobustan (Bayanata microblock) belong to the Lower Miocene, but Shekikhan, Aghdam, Ayrantoken, Dashgil and Bahar are registered in South Gobustan (Toraghay microblock), as well as the mud volcanoes of the Lower Kura (Boyuk Heremi, Yandere, Durovdagh and Duzdagh), related to the Pliocene and Quaternary deposits [2; 10].

Below is a brief description of one typical mud volcano for each region.

The **Kichik Mereze mud volcano** is located 80 km west of Baku, on the top of a mountain with an absolute height of 600 m. The western and southern slopes of the hill are steep, while the northern and eastern slopes are gentle. The slopes are covered with shallow ravines and hollows. The breccia cover is 79 ha. The volcano is located in the northwestern periclinal of the Mushkamir anticline, on Miocene deposits (Fig. 2) [2; 10].

The **Bahar mud volcano** is located 57 km southwest of Baku, 6 km northeast of the Alat railway station, on the shores of the Caspian Sea. The absolute height of the volcano is 26.2 m. The size of the volcanic edifice is 1.75 x 1.3 km, the relative height is 45 m. It consists of small hills. The area of its breccia cover is 143.8 ha, the thickness near the eruption center is 70 m, along the edges it is 20 m [2; 10]. The volcano is located in the northwestern pericline of the Alat-Deniz fold, which stretches in the west-northwest and east-southeast directions. The arched part of the fold is formed by the Productive Series (Plioce-

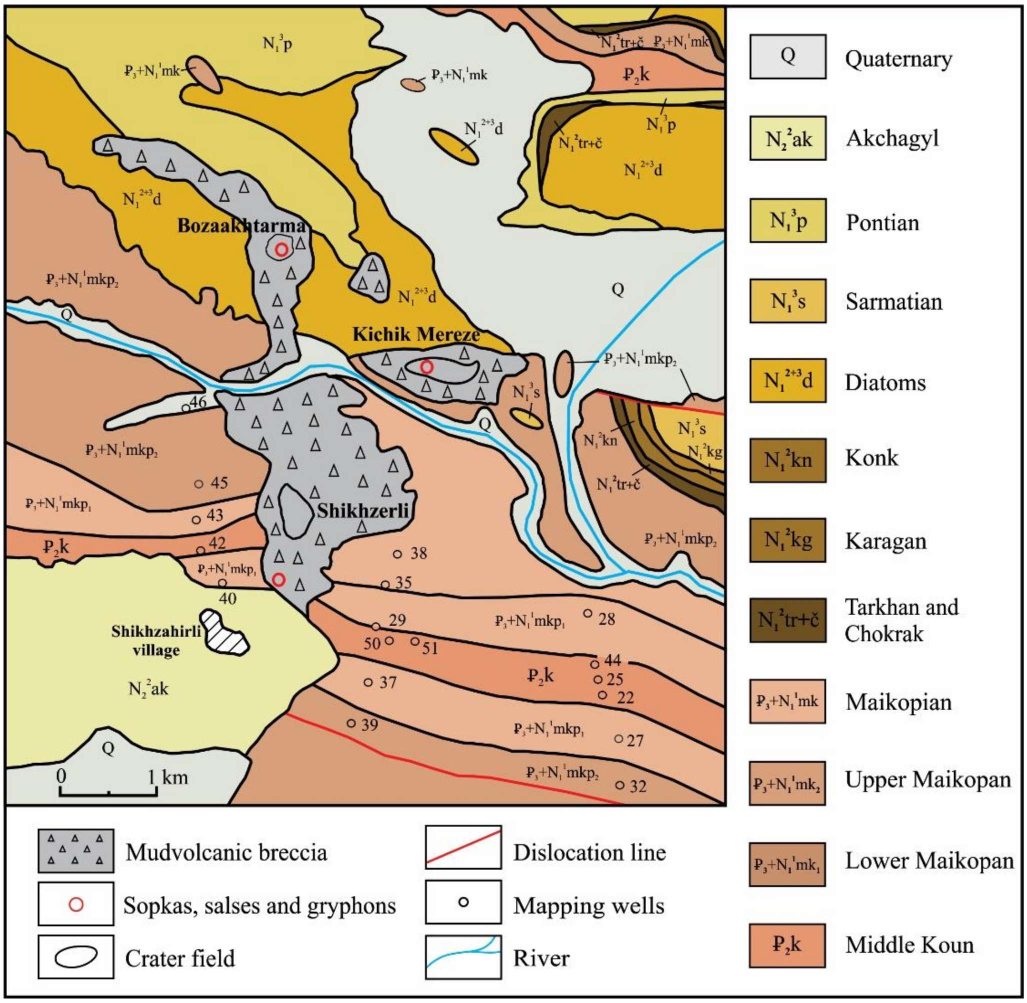

Fig. 2. Geological map of the Kichik Mereze mud volcano area

ne) deposits, and the limbs are formed by the Aghchagil (Pliocene) and Absheron deposits (Quaternary). The fold is complicated by three longitudinal and transverse faults. The volcano is located at the junction of a central longitudinal fault and a transverse fault separating the Alat Deniz and Dashgil uplifts (Fig. 3) [2; 10].

The **Durovdag mud volcano** is one of the most active (gryphon-salse activity) volcanoes in the south of Azerbaijan. It is located 16 km southeast of the city of Salyan. The relative height is 25 m, the size of the edifice is 1 x 0.8 km, and the diameter of the crater is 1 km. Volcanic breccia has an area of 54 ha, an average thickness of 60 m, and a volume of 30 million m^3 [10]. This volcano is located at the intersection of longitudinal and transverse faults. According to the seismic exploration data, two transverse faults to the northwest and southeast of the volcano separate the Durovdag area as an independent tectonic block (Figure 4) [10].

Results and discussion. The obtained results on chemical compositions make it possible to reveal some regularities in terms of geological structure and space. Thus, the breccias of the Kichik Mereze mud volcano, located in the Central Gobustan, together with Shekikhan, contain higher concentrations of Si and Al. Samples with the lowest Si content are characteristic of the Lower Kura mud volcanoes, where the youngest (Quaternary) deposits have been recorded. Relatively high contents of Mg and P are also noticeable in the samples of these mud volcanoes. High Ca is also characteristic of those volcanoes located near the Caspian Sea. The indicators showing a sharp difference among the studied samples are typical for the Agdam volcano. The sample from this volcano contains the smallest amount of SiO_2 (36.16 %) and the largest amount of Na_2O (16.62 % (see Table 1)).

Mud volcanoes of the Lower Kura oil and gas region, located closer to the sea, are rich in trace elements such as Li, Ga, Rb, Zr, Mo, Cs, Pr, Tl, Pb, Th, U and others, but are depleted in Ni, Sr, Ba and etc. In addition, high concentrations of Li, V, Zn, Rb, Zr, Cs, Pb and some other trace elements are recorded in the samples belonging to Kichik Mereze and Shekikhan. Ni and Sr are less common in those samples. In addition to U, an excess amount of Ba is determined in the sample from Shekikhan. The sample taken from Aghdam mud volcano has the lowest concentrations of Ni and Ba, but high Mo (Table 2).

The Rb/Sr vs. Rb/Ba ratios indicate an associa-

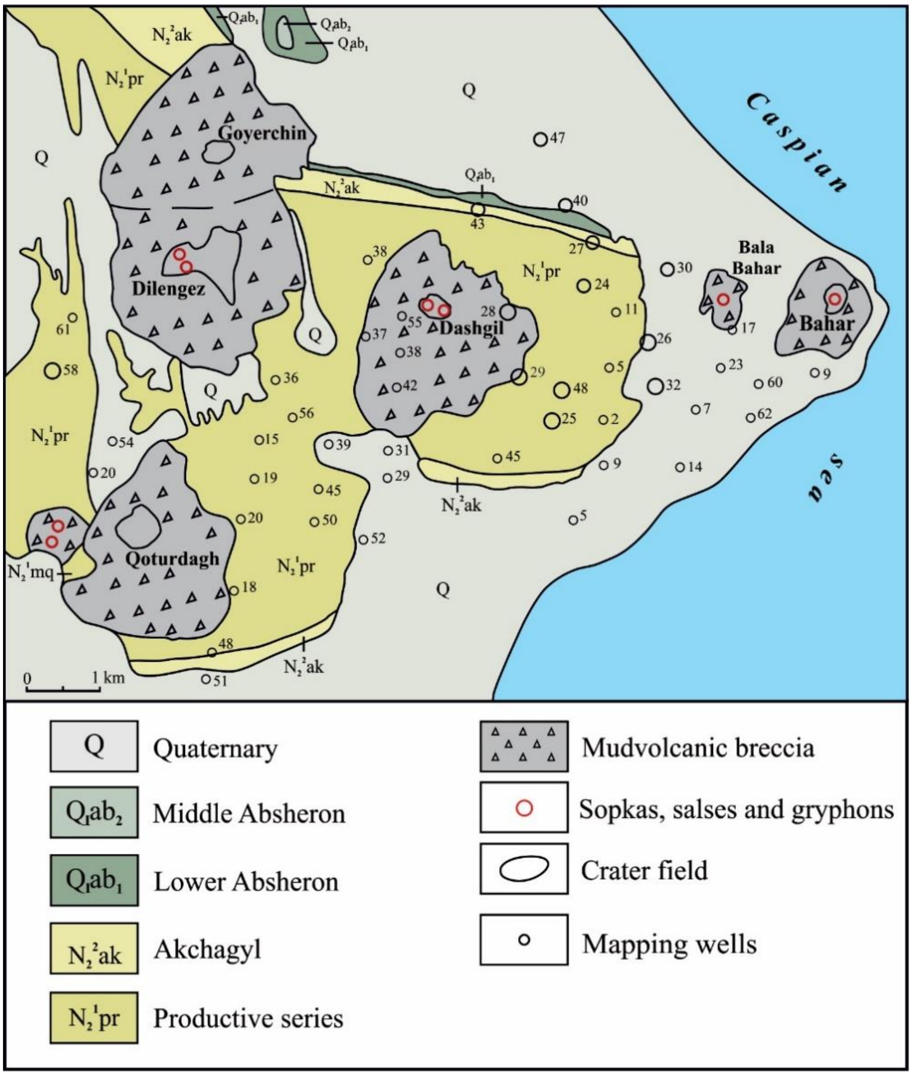

Fig. 3. Geological map of the Bahar mud volcano area

tion between mudvolcanic breccia sediments and plagioclase-rich parent rocks (Figure 5), which is considered [4] a characteristic feature of the primary sources of Cenozoic clay-rich sediments in the study region. Among the generally immature sedimentological samples, the parent rocks of some samples, especially the protolith of the Kichik Mereze mud volcano breccia, show a more mature trend. This is probably due to the higher contribution of Upper Maikop sediments to the formation of the breccia of this mud volcano. The result of studies carried out in [9] shows that the protoliths of some Upper Maikop oil shales, containing more quartz (about 40%) and having more mature features in Central Gobustan are associated with granitic sources. Another interesting issue relates to the higher U values in the Aghdam and Shekikhan samples (Table 2), which, like Kichik-Mereze, are separated from other samples in the Rb/Sr vs. Rb/Ba plot. The preservation of high amounts of U in organic-rich rocks can be explained by the role of U leached from tuffaceous rocks genetically associated with a more acidic composition. This idea is consistent with the conclusion made in [9]. Thus, this literature shows that pyroclastic sediments brought into the paleobasin play a decisive role in the formation of Middle Eocene and Diatom oil shales [11] rich in organic matter (on average about 20 %) in Central and Southern Gobustan.

The analysis of major oxides shows that the spatial position of the paleobasin of deposits belonging to the breccias of 12 mud volcanoes is completely different. This is manifested mainly in the Mereze mud volcano, which belongs to Central Gobustan, as well as in Shekikhan, which belongs to Southern Gobustan. The localization of samples belonging to both volcanoes on the “A – K – F” diagram (Figure 6) allows us to attribute their paleobasin conditions to a more continental setting, especially in comparison with volcanoes located on the coast of the Caspian Sea. Thus, a conclusion is made about the greater influence of the marine environment on the formation of the Yandere, Duzdag and Durovdag breccia deposits located in the deepest depression of the Lower Kura. Interpretations related to the trace element composition of samples from these volcanoes also support this idea.

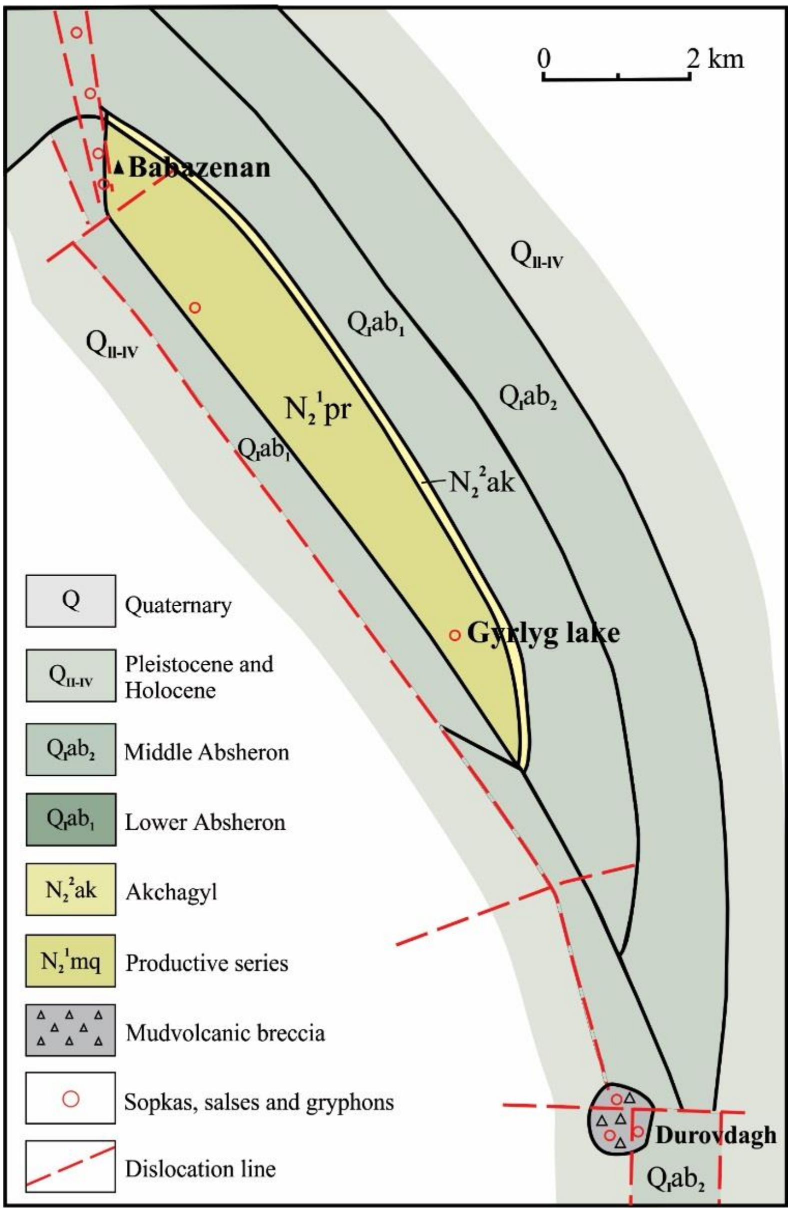

Fig. 4. Geological map of the Durovdag mud volcano area

Table 1

Oxides of major elements determined in gryphon breccia of mud volcanoes (%)

Mud volcano	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
Kichik Mereze	54.23	0.66	16.33	3.81	2.56	0.08	3.55	3.59	2.75	3.38	0.11
Shekikhan	54.47	0.62	15.55	3.25	2.78	0.08	2.85	3.16	3.47	3.00	0.13
Aghdam	36.16	0.45	11.52	2.17	2.03	0.07	2.53	2.52	16.62	2.22	0.10
Ayrantoken	52.52	0.53	12.61	2.40	2.97	0.11	2.83	8.23	3.64	2.09	0.14
Dashgil	51.24	0.55	12.40	2.92	2.23	0.09	2.50	7.09	5.34	2.23	0.14
Bahar	51.00	0.55	12.87	2.41	2.77	0.10	2.59	7.99	4.60	2.11	0.14
Deveboynu	49.33	0.58	13.81	3.35	1.98	0.13	2.74	8.91	3.19	2.72	0.13
Pilpile-Garadagh	50.48	0.61	13.91	3.48	2.30	0.11	2.78	8.43	3.28	2.26	0.14
Boyuk Heremi	49.95	0.58	12.40	2.68	2.56	0.11	2.87	8.31	4.87	1.95	0.15
Yandere	45.87	0.63	12.84	2.83	2.75	0.11	3.47	8.03	5.57	2.19	0.17
Durovdagh	42.70	0.56	11.53	1.80	2.68	0.09	3.03	6.98	9.19	2.05	0.15
Duzdagh	45.08	0.59	12.23	2.84	2.39	0.09	3.42	8.67	6.36	2.09	0.17

Table 2

Trace element composition of gryphon breccia of mud volcanoes (ppm)

Trace element	Kichik Mereze	Shekikhan	Aghdam	Ayrantoken	Dashgil	Bahar	Deveboynu	Pilpile-Garadagh	Boyuk Heremi	Yandere	Durovdagh	Duzdagh
Li	65,29	60,33	46,45	38,22	49,13	39,39	53,54	43,97	37,09	37,75	33,54	30,82
Be	2,38	2,11	1,51	1,52	1,57	1,43	1,95	1,66	1,22	1,72	1,55	1,36
Sc	16,92	15,34	11,93	13,57	12,93	13,59	14,07	15,17	14,50	15,46	13,21	13,66
V	189,32	232,57	151,96	126,15	130,81	125,08	136,96	139,12	125,47	134,59	115,56	126,17
Cr	112,71	103,96	78,81	83,82	79,77	79,41	86,11	87,90	85,08	103,47	97,06	110,56
Co	15,81	16,68	12,26	16,50	15,34	15,35	17,43	16,90	15,67	17,04	15,55	17,57
Ni	42,62	56,90	39,01	60,54	53,71	51,57	54,73	57,48	58,29	74,00	75,62	89,01
Cu	32,85	53,79	34,62	44,10	45,00	41,55	44,04	43,77	39,10	43,53	38,89	40,15
Zn	98,29	105,64	72,60	73,54	78,71	74,94	90,07	82,85	74,37	80,61	75,44	71,53
Ga	19,56	18,08	13,79	13,88	14,19	14,49	16,83	16,15	13,87	15,53	13,62	13,83
As	14,29	18,40	11,01	13,85	14,36	13,24	14,69	14,60	11,06	10,57	13,56	13,44
Rb	154,11	127,38	94,05	77,29	87,16	78,77	113,20	87,38	72,13	83,86	74,26	72,84
Sr	185,32	242,80	186,02	344,35	351,62	342,76	389,05	331,77	431,04	414,24	407,86	467,78
Y	19,33	18,79	14,01	16,57	16,58	15,45	18,61	17,29	15,83	15,98	14,15	15,25
Zr	125,43	110,66	86,71	81,82	85,10	72,86	100,38	96,39	71,45	83,85	64,82	71,66
Nb	11,12	10,13	7,08	7,81	8,09	7,65	9,12	8,34	7,73	9,77	8,60	9,17
Mo	1,85	10,14	6,78	3,37	3,83	1,77	4,64	2,79	1,13	1,32	1,43	1,03
Ag	0,35	0,27	0,21	0,21	0,21	0,17	0,23	0,18	0,16	0,18	0,16	0,14
Cd	0,26	1,34	0,63	0,28	0,37	0,25	0,31	0,31	0,26	0,25	0,22	0,21
Sn	3,40	2,41	1,61	1,53	1,96	1,44	2,04	1,66	1,38	2,52	1,48	1,36
Cs	11,60	8,27	6,22	4,26	5,06	4,48	7,22	5,24	4,02	5,10	4,31	3,96
Ba	285,41	380,11	273,88	385,99	347,85	372,09	526,31	364,68	366,62	366,02	353,48	408,57
La	29,65	26,65	19,34	19,84	21,59	20,28	25,95	22,55	20,62	22,39	20,17	20,96
Ce	67,41	61,99	44,45	46,08	50,51	47,31	59,49	51,97	45,56	51,84	45,36	47,50
Pr	6,97	6,38	4,67	4,84	5,31	4,91	6,35	5,51	4,85	5,40	4,77	4,89
Nd	25,56	23,40	17,05	18,48	19,88	18,27	23,12	20,43	18,17	20,51	17,89	18,22
Sm	4,97	4,69	3,40	3,89	4,07	3,75	4,53	4,17	3,77	4,18	3,66	3,73
Eu	1,04	0,97	0,70	0,87	0,89	0,87	0,96	0,96	0,87	0,93	0,84	0,89
Gd	4,27	3,92	2,80	3,37	3,54	3,39	4,02	3,74	3,45	3,63	3,16	3,33
Tb	0,68	0,62	0,47	0,54	0,56	0,53	0,64	0,60	0,55	0,58	0,50	0,53
Dy	3,66	3,54	2,62	3,04	3,07	2,90	3,44	3,24	2,98	3,11	2,70	2,91
Ho	0,73	0,68	0,53	0,60	0,62	0,58	0,67	0,64	0,58	0,60	0,53	0,55
Er	2,17	2,05	1,65	1,79	1,76	1,64	1,98	1,83	1,72	2,00	1,66	1,55
Tm	0,32	0,29	0,24	0,25	0,25	0,23	0,29	0,26	0,23	0,25	0,21	0,23
Yb	2,13	1,99	1,57	1,62	1,63	1,54	1,91	1,72	1,57	1,52	1,46	1,48
Lu	0,31	0,30	0,26	0,24	0,24	0,22	0,26	0,25	0,23	0,23	0,21	0,21
Hf	3,34	2,93	2,18	2,05	2,28	1,93	2,69	2,43	2,03	2,12	1,81	1,89
Ta	0,83	0,70	0,51	0,53	0,55	0,52	0,64	0,59	0,52	0,65	0,58	0,58
W	2,41	1,53	1,01	0,96	1,10	1,00	1,51	1,06	0,96	1,14	1,05	0,94
Tl	0,60	0,80	0,42	0,35	0,41	0,33	0,51	0,39	0,31	0,36	0,32	0,30
Pb	20,63	17,65	11,65	14,07	14,60	13,47	16,99	15,16	12,43	14,50	12,65	12,27
Th	11,03	9,58	6,84	6,44	7,23	6,54	9,23	7,29	6,79	7,47	6,90	6,50
U	2,41	4,55	3,02	2,23	2,24	1,66	2,91	1,96	1,59	1,84	1,75	1,71

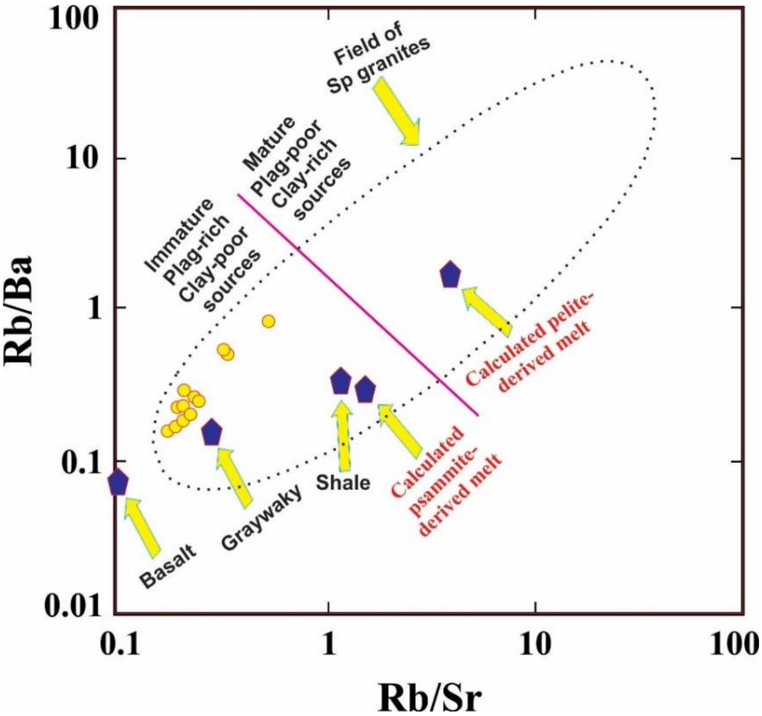

Fig. 5. Diagram of Rb/Sr vs. Rb/Ba for breccia samples

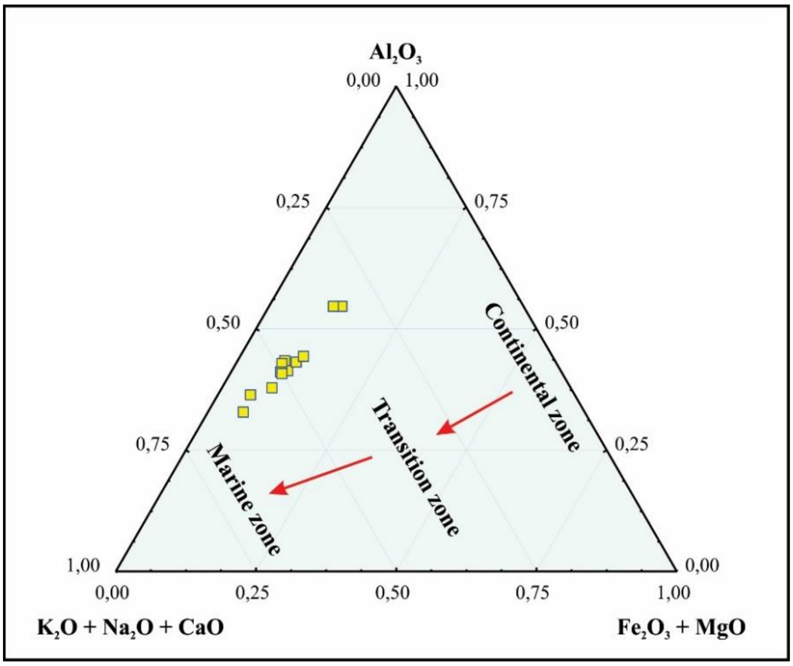

Fig. 6. "A – K – F" diagram showing the spatial distribution of paleobasins of sediments that formed breccias of mud volcanoes (diagram boundaries are presented with reference to [14])

As can be seen from Table 2, Ba and Sr are the trace elements found in the samples in the largest amount. The amount of these elements has different values for all studied volcanoes. However, an interesting genetic typomorphism is observed in the Ba/Sr ratios. As is known, isovalent, perfect Ba-Sr substitution occurs in most minerals, including Ba (as well as in Sr)-containing compounds. Depending on the ratio of these two elements in a mineral, its genetic nature changes [12]. Thus, a high Sr/Ba ratio in a mineral is indicative of the mineral's genesis with marine deposits, but relatively low depositional rates are associated with land-sea transition or continental areas [6]. The paleobasin conditions of the breccias of 8 of the 12 studied mud volcanoes clearly show a closer relationship with the sea, which is also confirmed by the "A – K – F" diagram in terms of the composition of major elements (Figure 7). For greater clarity, the samples related to the mud volcanoes Kichik Mereze, Shekikhan, Aghdam, and Deveboynu are consistent with the setting of the land-sea transition. However, samples from Ayrantoken, Dashgil, Bahar and

Pilpile-Garadagh, and especially Yandere and Boyuk Heremi, located in the north of the Lower Kura, as well as the mud volcanoes Durovdagh and Duzdagh of the same region, located closer to the boundaries of the modern sea, show a connection with the marine environment.

The V/Cr indicators of the samples point to the dominant role of oxygen-rich environments in the formation of breccia belonging to the mud volcanoes of Azerbaijan (Figure 8). From this point of view, the samples related to the mud volcanoes of Lower Kura are particularly different. Samples from the Shekikhan and Aghdam mud volcanoes show a connection with paleobasin conditions that are comparatively less oxygenated.

Some of the obtained results on the spatial position of the paleobasin deserve attention. Thus, the fact that the Boyuk Heremi and Yandere, located far from the modern sea boundary, in the north of the Lower Kura, and the volcanoes of the same region, located not far from the modern sea, show a connection with marine sediments requires explanation. In our opinion, this can most likely be explained by the geological age of the deposits that made up the composition of the breccia and the depth of the mud chambers under the mud volcanoes. It is known that deposits belonging to different stratigraphic units contribute to the formation of breccias to varying degrees. The thickness of the sedimentary cover in coastal areas belonging to the deepest part of the Lower Kura depression is about 20 km, half of which consists of Neogene and younger deposits [19]. However, the thickness of the sedimentary cover in the areas of the volcanoes belonging to the northern part is much less; therefore, the maximum contribution of older deposits, Paleogene, especially Eocene, to the

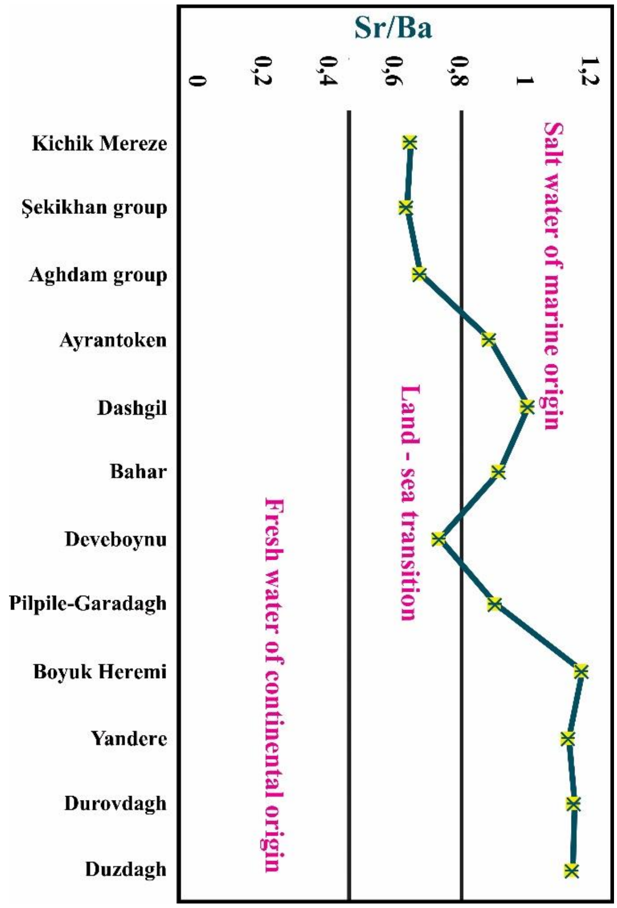

Fig. 7. Diagram showing the areas of spatial occurrence of sediments associated with the sampled mud volcanic breccias (diagram boundaries are presented with reference to [14])

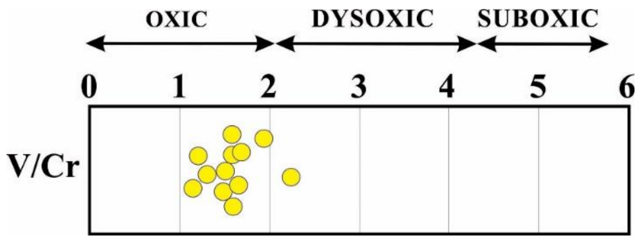

Fig. 8. V/Cr plot showing paleoredox conditions of mud volcanic breccia samples

formation of breccias belonging to these volcanoes cannot be ruled out [9]. If we take into account the published results of studies of the relationship of Eocene deposits with the sea in East Azerbaijan [13; 14], the correctness of our conclusion is beyond doubt. On the other hand, when studying volcanoes with different morphological characteristics, it was found [20; 21] that the depths of primary mud chambers in conical mud volcanoes are greater than in flat-topped ones. If we refer to such a pattern, then we can assume that the initial chambers of all four volcanoes of the Lower Kura, which belongs to plateau-like volcanoes, are relatively close to the earth's surface. Since the breccias studied by us belong to the gryphon (and not the product of the eruption), it can be assumed that mud related to the primary mud chamber participated in their formation to a greater extent. Approaching from this point of view, the contribution of deeper deposits to the formation of breccias of mud volcanoes located in the south of the Lower Kura, in the coastal zone, where the sedimentary layer is quite thick, can be considered minimal. This means that the role of Eocene deposits, better connected to the sea [13; 14], in their formation is less, and this influence was higher for volcanoes noted in the steeper north of this area. However, the fact that the sediments formed by the breccias of mud volcanoes located in the southern coastal parts of the Lower Kura were deposited under marine conditions is not at all denied. The main issue is the explanation of a closer connection with the sea, in which, in our opinion, geological factors had a decisive influence.

Conclusion. Compared to the mud volcanoes recorded in the areas where the Quaternary sediments are spread in Lower Kura, the breccia of the Kichik Mereze mud volcano located in the northernmost part of Gobustan (in the areas where the Maykop sediments are spread) contains higher Si and Al together with Shekikhan. High Ca is characteristic for volcanoes located near the Caspian Sea.

Plagioclase-rich source rocks and oxygen-dominated paleobasin environments played a key role in the formation of breccia deposits belonging to the mud volcanoes of Azerbaijan.

Geochemical proxies make it possible to link the paleobasin conditions of the formation of the gryphon breccia deposits of most mud volcanoes of Southern Gobustan, including Kichik-Mereze, located in Central Gobustan, with the continental setting, especially in comparison with some volcanoes of the Lower Kura, as well as Gobustan and Absheron, located on the shores of the Caspian Sea and relatively close to it.

The fact that the breccias of mud volcanoes located at a relatively large distance from the modern sea boundary and in the steepest northern part of the Lower Kura are associated with marine conditions, as are breccias of mud volcanoes located in the south of this tectonic zone (subjected to intense subsidence) and at a short distance from the Caspian Sea, may be due to geological factors. This is explained by the fact that: 1) the thickness of the sedimentary cover of the deep-depression part of the Lower Kura (coastal zone) is about 20 km, half of it consists of Neogene and Quaternary deposits; 2) the thickness of the sedimentary cover in the volcanic regions located in the north of this zone is much less and the role of older (Paleogene) deposits in the formation of mud volcanic breccias here, especially Eocene ones deposited under marine settings in East Azerbaijan.

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Геохімічні прояви сопкової брекчії грязьових вулканів Східного Азербайджану: закономірності розподілу хімічних елементів та просторові характеристики осадонакопичення

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Ця стаття була присвячена дослідженню вмісту хімічних елементів у сопкових брекчіях 12 активних грязьових вулканів у таких нафтогазоносних районах Азербайджану, як Абшерон, Гобустан та Нижня Кура. Хімічний склад зразків брекчії, використаних у дослідженні, було проаналізовано з використанням сучасних приладів, таких як спектрометр "S8 TIGER Series 2" та мас-спектрометр "Agilent 7700 Series ICP-MS". У дослідженнях представлена велика інформація про особливості геологічних характеристик грязьових вулканів, розташованих у різних тектонічних зонах, а також детально описані супутні елементи, такі як Si, Mg, P, Li, Ga, Ga, Rb, Zr, Mo, Cs, Pr, Tl , Pb, Th, U, Ni, Sr, Ba та інші. На основі отриманих даних було виявлено джерела матеріалів, які відіграли роль у відкладенні брекчій вулканів на території Азербайджану, а також за допомогою комплексних геохімічних методів було реконструйовано середовище накопичення осадів. На основі результатів, які були отримані з використанням геохімічних індикаторів, також оцінено характеристики палеобасейну, що впливають на формування сопкових брекчій в Абшеронському районі, на Південному та Центральному Гобустані, а також на півночі та півдні Нижньої Кури. Відмінність у хімічній природі брекчій розглядається між вулканічними зонами Азербайджану, які розташовані як поблизу, так і далеко від Каспійського моря. У цих відмінностях особлива увага приділяється ролі морфологічних особливостей вулканів, глибині залягання грязьових камер та головним чином геологічним факторам. На основі отриманих даних узгоджуються закономірності у тектонічних зонах та районах, а також були визначені відповідні зміни у хімічному складі, та пропонуються нові ідеї, які пов'язані з регіоном та з урахуванням відповідних сучасних літературних матеріалів.

Ключові слова: *сопочна брекчія, хімічний склад, закономірності розподілу, умови осадонакопичення.*

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