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GEOLOGY

New Data on Cenozoic Subalkaline Rocks of Eastern Iran

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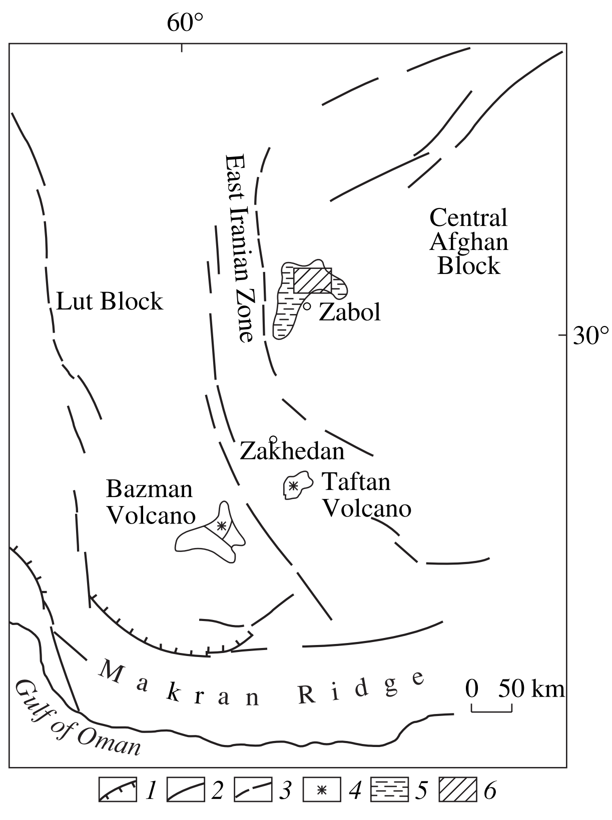
The Baluchestan and Sistan territory of eastern Iran is interesting in terms of geology, but it remains poorly studied for political and geographical reasons. This territory was investigated at the end of the 1990s by a geological team headed by A. Hushmand-Zadeh, M.A.A. Nogol Sadat, and E.F. Romanko. The submeridional East Iran Zone and western part of the Afghan Block (Helmand Depression) were previously thought to be composed of sedimentary rocks with sharply subordinate igneous rocks [1, 2, 4–12] (figure), and the role of igneous rocks appeared to be substantially higher [3]. The present communication offers new data on the insufficiently investigated subalkaline volcanics developed among the dominant thick calc-alkaline volcanoplutonic sequences [1, 3, 8, 10, 13].

Subalkaline intraplate rocks constitute separate nearly isometric structures and individual volcanoes (from a few hundreds of meters to several kilometers across) in the desert area of eastern Iran, western Afghanistan, and northwestern Pakistan. The approximate age of these volcanics ranges from the Paleogene to the Quaternary. The Haneshin carbonatites of western Afghanistan, which are coeval, in my opinion, with the examined rocks, are referred to the Quaternary [1]. Neogene basaltic trachyandesites (here, this terminology is accepted instead of the former traditional one [14, 15]) in samples R70 and R71 are characterized by the relatively low $^{87}Sr/^{86}Sr$ (I_{Sr}) values of 0.7039 ± 0.20 and 0.70489 ± 0.18, respectively (analyst M.I. Bujakaite, Geological Institute of the RAS). These estimates and the I_{Sr} value of 0.7049 obtained for rocks from one of the unnamed volcanoes [7] are unique for the study region.

Under microscope, the rocks are observed as dark to black fine-grained formations with exhalation-related alterations. Fluid textures are rare. Sometimes, one can see thin brecciated zones. Altered varieties enclose abundant cavities filled with calcite, hematite, zeolites, red garnet, and clay minerals. The rocks are characterized by oligophyric and aphyric textures with contents of plagioclase and subordinate monocline pyroxene phenocryst exceeding 1/15 of the rock volume. The groundmass has a microlitic and less common bostonitic texture. One can define two groups of rocks differing in the formation depth. The first group (deeper variety) developed in the drying Lake Haji (Sample R71) and contains platy andesine (more calcic plagioclase). The groundmass hosts labradorite laths and an abundant dispersion of clinopyroxene and rutile prisms, small crystals of brown Ti-hornblende and pumpellyite, and grains of albite–oligoclase and clinozoisite. The



Location of the study area.

(*1–3*) Fractures: (*1*) with the strike-slip component, (*2*) proven, (*3*) assumed; (*4*) Cenozoic magmatic areas with volcanoes of the central type; (*5*) bottom of a depression in desert (playa); (*6*) study area.

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Table 1. Chemical compositions of volcanics from eastern Iran and some other subalkaline rocks

Component	1	2	3	4	5	6	7	8
SiO_2	57.80	54.50	52.76	62.88	60.20	50.02	50.13	58.67
TiO_2	1.31	1.87	1.11	0.66	0.48	1.96	2.52	1.70
Al_2O_3	17.48	15.94	17.44	17.42	16.90	15.90	15.71	15.13
Fe_2O_3	4.37	6.39	3.14	4.20	4.00	–	–	6.69
FeO	1.07	0.40	5.40	0.48	0.30	11.55	11.69	2.19
MnO	0.09	0.09	0.13	0.11	0.08	0.17	0.18	0.09
MgO	2.27	3.37	5.55	1.26	1.40	7.14	5.25	2.28
CaO	7.10	7.58	8.62	3.68	4.12	8.81	8.37	1.77
Na_2O	5.11	5.81	3.46	3.33	3.88	3.12	3.76	5.06
K_2O	1.42	1.73	1.31	3.41	6.31	1.02	1.81	2.05
P_2O_5	0.61	1.05	0.40	0.24	0.20	0.32	0.58	0.30
Rb	19	20	–	98	255	18	33	47
Ba	293	–	–	–	–	415	653	557
Sr	912	4470	–	308	844	431	735	263
Ni	53	58	–	8	11	122	135	44
Co	–	–	–	–	–	40	45	21
Cr	60	38	–	11	10	176	283	72
V	95	–	–	–	–	–	263	107
Cu	65	64	–	32	50	29	250	33
Zn	88	113	–	48	73	100	–	82
Pb	8	51	–	17	47	5	–	10
Zr	232	339	–	164	270	163	265	219
Y	19.5	25	–	20	38	–	–	23
Nb	17	19	–	16	19	26	83	30
Sc	10.7	–	–	–	–	21.3	23	10
Th	3.65	–	–	–	–	1.6	3.8	12
U	0.99	–	–	–	–	0.76	–	3
La	32.4	–	–	–	–	28.5	86.6	35.2
Ce	68.3	–	–	–	–	46.0	133.5	64.2
Nd	31.4	–	–	–	–	29.5	–	25.0
Sm	6.00	–	–	–	–	5.8	–	5.1
Eu	2.11	–	–	–	–	–	–	1.9
Gd	5.08	–	–	–	–	–	–	4.8
Tb	0.78	–	–	–	–	–	–	0.9
Er	1.64	–	–	–	–	–	–	1.6
Yb	1.26	–	–	–	–	2.5	3.4	1.6
Eu/Eu*	1.12	–	–	–	–	–	–	1.09

Note: (1–5) Eastern Iran, subalkaline and alkaline (5) rocks: (1) Zabol area (R70), (2, 4, 5) from [7], (3) Hash area; (6, 7) intraplate volcanics and trap rocks from other regions, average [14]; (8) Paleoproterozoic rocks from continental rift (Kuetsjarvi Formation, Pechenga Zone, Baltic Shield; original data); $N = 20$. (–) No data.

rocks demonstrate slight propylitization. The second group includes shallower rocks represented by scoriaceous and other varieties of volcanics with the glassy groundmass (Sample R70, desert area approximately 48 km northeast of the Zabol Settlement). The aggregate of twinned andesine laths is dominant. The rock is composed of normative plagioclase (78–84%) and clinopyroxene (10–15%). Prisms of brown Ti-hornblende and acicular rutile occur in association with prismatic monocline pyroxene. Mesostasis is represented by volcanic glass with gaseous vesicles and dispersed dust-sized magnetite. Of particular interest is red high-relief garnet with corroded facets. The rocks enclose abundant size-variable pores filled with a fine aggregate of serpentine, calcite, and zeolite of the analcime group that probably includes wairakite (a Ca-containing isomorphic variety). The comprehensive mineralogical study with a JSM-5300 scanning electron microscope (Japan) and other devices revealed that the rapid cooling of alkaline–subalkaline melt highly saturated with fluids was accompanied by the decomposition of some phases. For example, the rocks contain ilmenite that represents a product of the titanomagnetite decomposition, anatase developed after rutile within the polymorphic series, alkaline feldspar varieties, and others.

The examined K–Na basaltic trachyandesites and trachyandesites are intermediate in terms of K content, which is an important classification criterion [13–15]. They are principally different from the calc-alkaline volcanic and plutonic rocks that sharply predominate in eastern Iran.

Judging from geological, geochemical, and mineralogical properties, the rocks from the Haji area belong to the first group; i.e., they are deeper in origin. They demonstrate relatively *high* concentrations of many rare elements (mafic components, in particular) typical of intraplate specifics, such as Ni, Zn, Sr (up to 0.44%), Ca (Sr and Ca in the examined rocks vary in the antiphase manner, because their behavior is governed by more than just plagioclase and the presumably associated carbonatites are characterized by intricate petrogeochemistry), Ba (although it shows negative correlation with Ca in shallower rocks), LREE, Fe_2O_3, Cr, Mn, Ti (this is typical of intraplate rocks, in contrast to subduction-related varieties [14, 15]), Y, Zr, and P (sometimes more than 1.0%, which is very high for ordinary volcanics).

The shallower igneous rocks of the second group are characterized by medium K contents and elevated Ca concentrations, including up to 34% of syngenetic CaO (this is an additional feature typical of carbonatite rocks). In contrast to plagioclase, which shows a positive correlation with Ca and Sr, the Sr content (from 4470 to 180–500 ppm) has a negative or nonlinear correlation with Ca due to the presence of carbonate and other phases. The LREE content is low. For example, the La content is below 50 ppm, which is relatively low for carbonatite rocks and significant for subalkaline varieties (Tables 1, 2). On the whole, the following features are typical of these rocks: notably variable concentrations of many microelements; sometimes low Rb, Pb, and Ga contents; inverse correlation between Ba and Sr; indirect correlation between Ni and Sr; and insufficiently high Y concentration for intraplate rocks [14, 15]. It should be noted that Ca in rocks (partly, as plagioclase, amygdule-hosted zeolites, clinozoisite, and other phases) is not obviously a superimposed component.

Table 2. Concentrations of rare elements (ppm) in rocks of eastern Iran

Ord. no.	Sample	Rb	Sr	Y	Zr	Nb
1	R70-32	30	999	17	238	13
2	R70-28	30	912	20	232	11
3	R70-23	26	962	16	245	11
4	R70-3	29	932	17	231	9
5	R70-272	12	509	16	150	6
6	R70-271	4	165	15	76	5
7	R70-27	8	503	12	138	6
8	R70-99	10	505	12	145	8
9	R71-4	29	1185	26	279	23
10	R71-43	31	1182	25	286	22
11	Camp	20	4470	25	339	19
12	R25-99b	40	418	19	138	7
13	R82-3	8	426	7	138	5
14	Cartyp	4.5	3970	38	99	3.5
15	Lava	4	870	65	562	546
16	Melil	74	2935	59	141	691
17	Calc	7	3102	50	286	11
18	Foliated	11	2290	15	79	2.8

Note: (1–8) Unnamed volcano (R70), additional elements in 70-28: Sc 9.6, Y 9.8, V 95 (atomic absorption data); (9, 10) Haji Complex (R71), additional elements in 71-4: Sc 19, Y 20, V 220; (11) basaltic trachyandesite [7]; (12, 13) calc-alkaline complex of the Bazman Volcano (for comparison): (12) basaltic andesite, (13) rhyolite; (14–18) carbonatites (Larsen and Rex, 1992): (14) typical, (15) lava, (16) lava with pseudomorphs after melilite and nyerereite, (17) calciocarbonatite (sovite), (18) foliated.

One can observe a certain tectonomagmatic zoning in the region with younger structures located in the northeast owing to the regional subduction of the Neo-Tethys lithosphere in this direction. Both the dominant (frontal, in our case) Alpine calc-alkaline magmatism and the indirect Cenozoic intraplate (rear-zone) magmatism are related to this subduction. The second type of magmatism is exemplified by the Neogene and Neogene–Quaternary subalkaline and alkaline volcanics developed in eastern Iran, presumably Paleogene volcanics of the western Lut Block, and carbonatites of Afghanistan (Quaternary) and Pakistan (presumably, similar in age). Thus, intraplate magmatism together with the dominant calc-alkaline magmatism can be interpreted as a peculiar tectonomagmatic paragenesis. It implies at least a partial compensation of island-arc compression by intraplate tension and emphasizes the significant depth of the regional geodynamic process. Cenozoic intraplate rocks also occur in India and Turkey, suggesting the existence of a very large plume beneath the study region.

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