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Petrography and geochemistry of volcanic rocks of Molaahmad pass (East Isfahan, Centeral Iran)

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Key words: Calc-Alkaline, Geochemistry, Active continental margin, Volcanic rocks, Eocene, Urumieh-Dokhtar, Molaahmad pass, Central Iran.

Abstract

The studied area is located in east of Isfahan province. This area is the part of Uromiah- Dokhtar zone in Central Iran. Eocene volcanic rocks Mehrabad region (Molaahmad pass) consists mainly of intermediate-felsiclavasandesite to Dacite and pyroclastic rocks of the tuff. The volcanic rocks are composed of plagioclase, amphibole, quartz , opaque andglass. Most offerromagnesian minerals alterated to chlorite , cacite and epidote. On the base of geochemical studies, volcanic rocks are ranging from sub-alkalineandthey are a medium to high K calc-alkaline suite. In the Trace elements spider diagram, these similar to upper crust. They are generated partial melting of crustal protoliths. Enrichment in LILE and depletion of HFSE in the studied rocks as well as various petrologic diagrams point to magmatism in arc of an active continental margin.

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Introduction

The studied area located in east in Isfahan provine (central Iran) and apart of Uromiah- Dokhtar zone (Fig. 1). In Fig. 1, the location of the studied volcanic rocks in the vast Cenozoic postcollisional magmatic province is shown. Several studies have been done on tape volcanic Uromiah- Dokhtar zone (Emami, 1981; Amidi *et al*, 1984; Hassanzadeh, 1993; Aftabi and Atapor, 2000) indicating the existence of dominant calc-alkaline magmatic series and in some areas is shoshonite and adacite. In this area, based on the field type of volcanic rock, Volcaniclasic and Quaternary alluvial deposits are present. Volcanic rocks include Dasit- rhyodacite dyke andesites and basalts and tuffs of the Volcaniclasic rocks. (Amini and Amini Chehragh, 2003; Mehvari, 2009). The studied area is situated between longitudes of52°47′E and 52°58′Eand latitudes of 32°32′N and 32°41′N. The geological map of the study area, derived from the work of Amini and Amini Chehragh. (2003), is shown in Fig. 2 with Eocene age. At the field view, studied volcanic rocks are exposed as scattered hills and masses ranging in size from about 5 m to tens of meters. They overlie sedimentary units of Quaternary alluvial deposits. No metamorsphic effect is discoverable at the contact of the volcanic rocks, but just a little and limited alteration.The UDMA situated between the Sanandaj- Sirjan Zone (SSZ) and Central Iran runs parallel to the Zagros and the SSZ (Fig. 1). It forms a topographic ridge separating the SSZ from Central Iran and bears huge volcanosedimentary deposits, in places >10 km thick (Dimitrijevic 1973; Agard *et al.* 2011). UDMA is an Andean-type Cordilleran arc system (Dewey *et al.*, 1973) in the central Iran. This arc includes both intrusive and extrusive magmatic rocks and has resulted from subduction of Arabian plate beneath Eurasian plate (e.g., Emami 1981; Amidi *et al.*, 1984; Hassanzadeh 1993; Aftabi and Atapour 2000; Dilek and Sandvol 2009; Dilek *et al.* 2010; Agard *et al.*, 2011). UDMA is a part of a much larger magmatic province extending in a vast region of convergence between Arabia and Eurasia situated in the north of Zagros-Bitlis suture zone (Fig. 1) (Jackson and Mckenzie 1984; Dewey ***et al.***, 1986; Mcclusky *et al.*, 2000, 2003; Allen *et al.*, 2004; Dilek and Sandvol 2009). Cenozoic volcanic activities in this igneous province, and of course UDMA, mostly occurred in three time steps: late Eocene, late Miocene–Pliocene, and Plio- Quaternary (Dilek *et al.* 2010). The timing of their formation mostly coincides with and postdates a series of continental collision events in the region (Dilek and Whitney 2000; Dilek *et al.* 2010). Volumetrically, volcanic rocks were mostly produced during Eocene time (Farahoudi 1978; Shahabpour, 2005), with the oldest ones dating back to early Eocene time (55–50 Ma; Emami 2000).

Dasite and andesite rocks are important in the study area. The aim of this paper is study mineralogy, petrology, geochemistry and type of Dasite and andesite rocks in the Molaahmad pass. For determine rock groups and magma series. The volcanic rocks are assumed to the volcanic arc, these rocks the focus of the present study, and may reveal important information on tectonic setting of Uromiah- Dokhtar zone in this area.

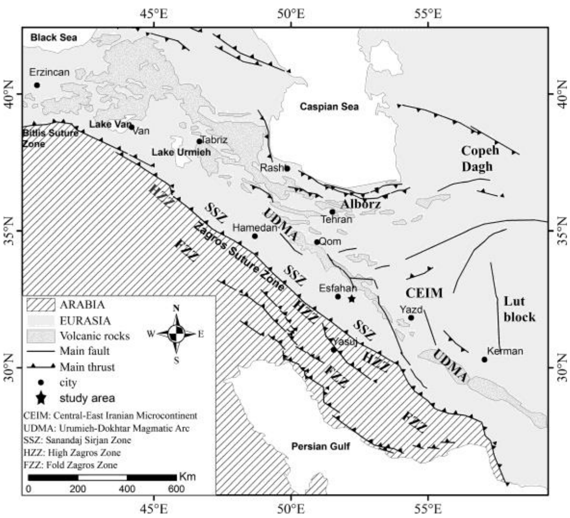


Fig. 1. Main tectonic units of Iran, distribution of the post-collisional volcanic rocks (Based on a combination of Hessami *et al.*, 2003, Dilek *et al.*, 2010, Agard *et al.*, 2011, Sayari, 2015) and the location of the study area.

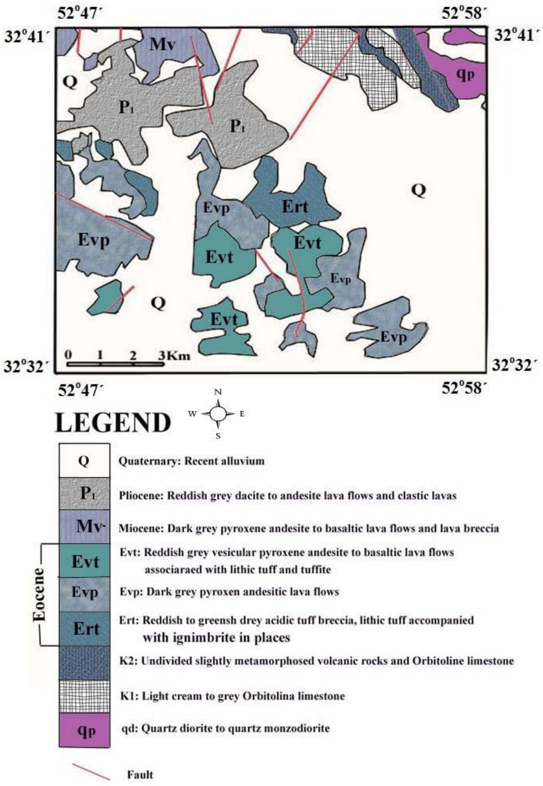


Fig. 2. Geological location of study area (modified from Amini and Amini chehragh, 2003).

Materials and methods

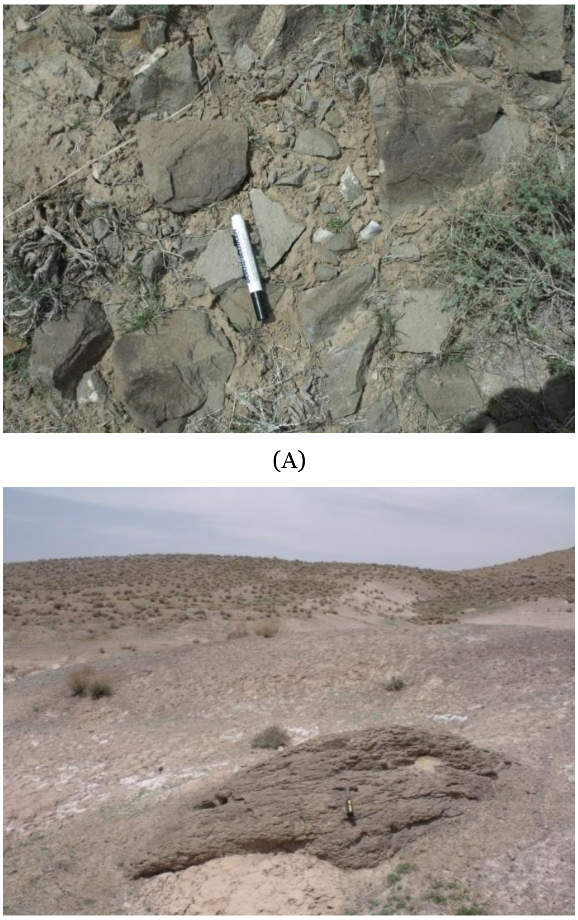
Sampling and Analytical techniques

A total of 70 relatively fresh samples were selected from the volcanic rocks of the study area. As a result, volcanic rocks are andesite to dasite. 8 samples after microscopy study were analyzed for major, trace and rare earth elements (REE) in the Zarazma laboratory (Tehran, Iran) by using ICP-MS (inductively coupled plasma mass spectrometry) after acid decomposition (Table 1). Samples (P2, P3, P4, R10, R11, R12) were analyzed for major and trace and rare earth elements by using ICP-MS in the ALS Chemex analytical laboratory (Vancouver, Canada) (modified from Mehvari, 2009).

Results and discussion

Petrography

In the point of a microscopic view, the studied volcanic rocks are mainly dacite and andesite (Fig3 A,B). The rocks show typical porphyritic textures of volcanic rocks such as hyalo-porphyritic, microlitic-porphyritic, and trachytic textures made of mainly phenocrysts of plagioclase, amphibole, and quartz in a matrix composing of feldspar, quartz, microlite and glass.



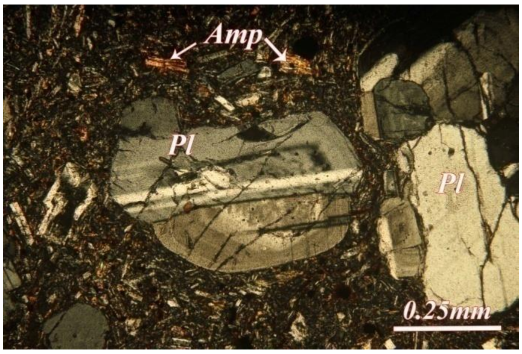
(A)

(B)

Fig. 3. A) Outcrop of andesite, B) Outcrop of dacite.

Andesite

Andesites are mainly fine to medium grained rocks. The mineral assemblage is typically dominated by plagioclase plus hornblende (Fig.4A). Pyroxene and opaque are common accessory minerals (Fig. 4B). Alkali feldspar, quartz may be present in minor amounts. Chlorite, epidot and calcite are secondary minerals (Fig. 4C). Some of plagioclase with rounded edges and have become the decomposition of calcite (Fig. 4D). The rocks show typical porphyritic textures of volcanic rocks such as hyalo-porphyritic, microlitic-porphyritic, sevie and trachytic textures.



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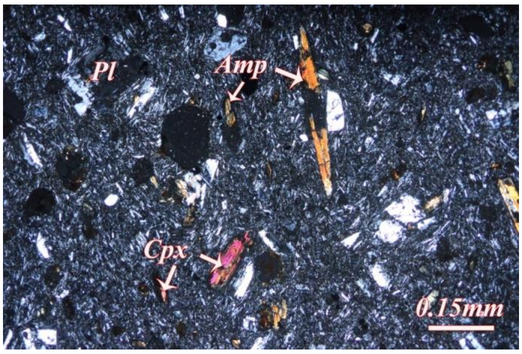

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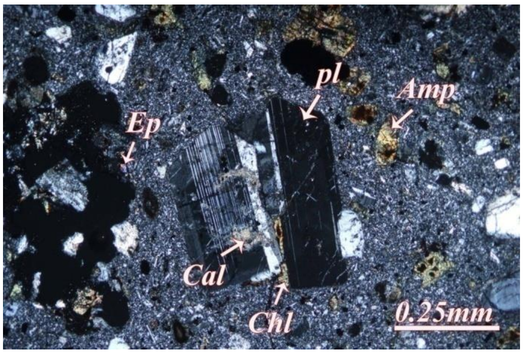

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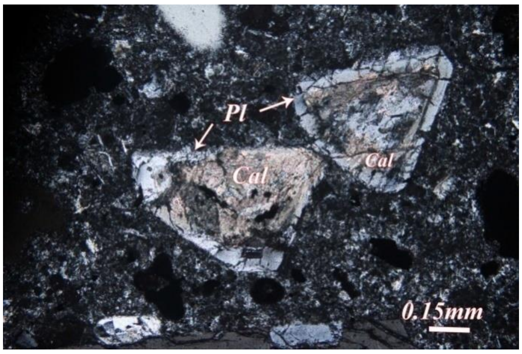

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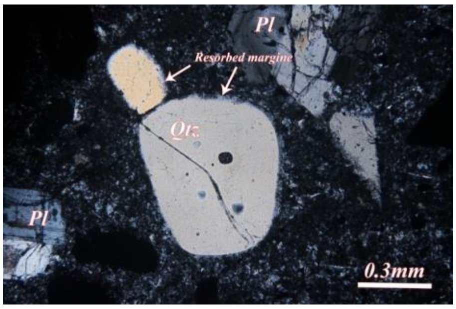
Fig. 4. A) Plagioclase phenocrysts with rounded margins with amphibole minerals, B) Amphibole phenocrysts with clinopyroxene in plagioclase microlits. C) Plagioclase alteration of calcite, epidote and chlorite, D) Secondary calcite of plagioclase alteration.

Dacite

Dacite main minerals include plagioclase, alkali feldspar, quartz and amphibole was Opacity. Some of the quartz with rounded margins, corrosion Gulf seen and the number have seen Resorbed margine (Fig.5A).Plagioclases have Pericline-albite, albite-carlsbad twins are accompanied by amphibole and opaque (Fig. 5B) and the number of oscillatory zoning (Fig.5C). Opacities of hornblende in dacite , according to some researchers, the rapid drop in pressure is concerned (Rutherford, 1993). It is believed that the stability of these minerals reduces pressure drop and release them into, As a result, a black border around like hornblende crystals formed (Fig.5D). The volcanic rocks have porphyritic texture, but according to some thin sections, hyalo-porphyritic textures have been observed.



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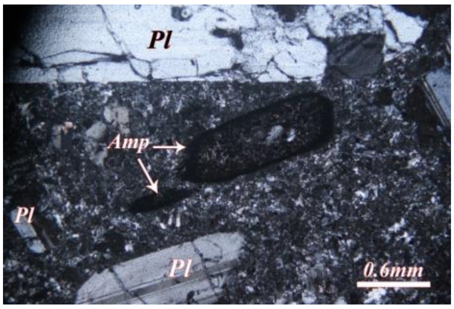

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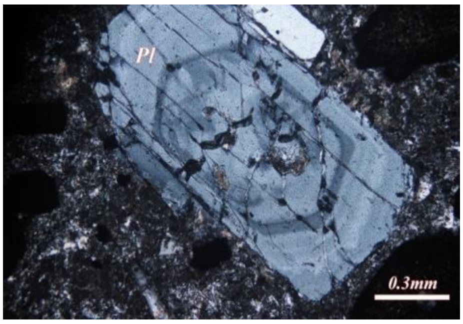

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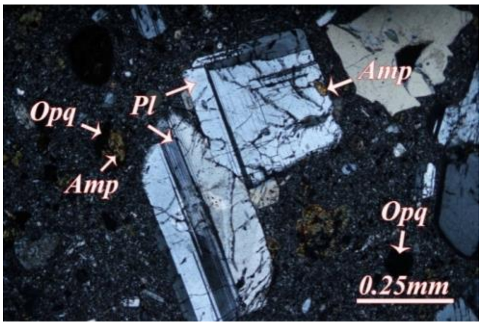


(D)

Fig. 5. A) quartz with Resorbed margine, B) Plagioclase with Pericline-albite, albite- carlsbad twins, C) oscillatory zoning in plagioclase, D) Opacities of hornblendein dacite.

Geochemistry

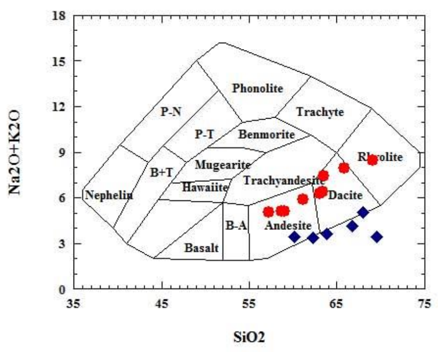
Results of whole-rock geochemical analysis of all samples are presented in Table 1. The Volcanic samples display SiO_2, Al_2O_3, K_2O and MgO content sranging from 57.2 to 69.5, from 11.74 to 16.91 , from 0.85 to 2.57 and from 0.19 to 2.52 wt% respectively.

On the base of geochemical diagrams, the total alkalis vs. silica (TAS) diagram of Cox *et al.* 1979 and Winchester and Floyd, 1977 (Fig. 6 A,B). The samples plot in the andesite to dacite field of this diagram (Fig. 6 A,B).

Table 1. Major (Oxides: %wt) and trace elements (in ppm) data for volcanic rocks in study area.

Sample	M4	M5	M24	M26	M2	M7	M8	M9	P2	P3	P4	R10	R11	R12
Rocks name	Andesite	Rhyolite	Dacite	Dacite	Dacite	Andesite	Andesite	Dacite	Dacite	Andesite	Andesite	Dacite	Dacite	Dacite
SiO_2	61.14	69.03	63.47	63.39	65.8	59	57.2	63.1	67.98	60.14	62.3	69.5	63.8	66.7
Al_2O_3	16.48	11.74	16.91	15.54	15.1	16.5	16.6	16.6	12.69	12.84	12.51	10.45	13.9	12.7
Fe_2O_3t	5.414	1.26	4.12	4.84	3.45	7.07	6.71	5.53	3.24	3.16	2.47	4.48	1.58	3.28
CaO	5.31	1.11	5.1	4.06	1.8	5.89	6.01	5.3	2.56	6.11	4.87	0.63	3.01	1.84
MgO	2.19	0.19	0.62	2.01	1.05	2.36	2.57	1.92	0.77	2.5	2.35	2.17	2.52	2.26
Na_2O	4.4	6.46	4.81	4.82	4	3.2	3	3.6	3.11	2.56	2.45	2.4	2.8	2.67
K_2O	1.5	1.98	2.63	1.58	3.92	1.89	2.04	2.65	1.91	0.87	0.94	1.02	0.85	1.45
Cr_2O_3	<	<	<	<	<	<	<	<	0.001	0.005	0.004	0.001	0.001	0.001
TiO_2	0.56	0.06	0.5	0.45	0.35	0.72	0.65	0.51	0.44	0.47	0.23	0.17	0.21	0.32
MnO	0.09	0.06	0.09	0.08	0.08	0.13	0.12	0.1	0.03	0.13	0.12	0.02	0.12	0.05
P_2O_5	0.13	0.02	0.24	0.12	0.1	0.15	0.18	0.19	0.1	0.12	0.06	0.04	0.05	0.1
BaO	0.07	0.06	0.14	0.07	0.1	0.08	0.09	0.17	0.05	0.06	0.07	0.21	0.06	0.04
LOI	2.72	8.03	1.37	3.03	2.78	1.94	2.09	1.79	7	10.9	11.5	8.73	11	9.15
Total	100	100	100	99.99	98.4	98.8	97.2	101.3	99.84	99.8	99.81	99.9	99.9	100.5
Ag	<0.1	<0.01	0.1	<0.1	<1	<1	<1	<1	12.9	82.8	5.3	<1	<1	<1
Ba	464	517	935	454	860	720	890	1050	424.6	531.5	606.6	1965	559	412
Ce	26	60	58	27	39.4	31.5	32.1	49.2	29.4	32.8	28.7	19.6	31.6	32.1
Co	13.2	<1	9.6	11.5	5.8	16.7	17.6	11.9	4.8	9.1	6.6	6.8	7	8
Cr	15	4	12	20	<0. 1	<0. 1	<0. 1	<0. 1	6.84	12.21	23.47	7.93	6.84	6.04
Cs	0.5	22.4	1.7	0.7	3.7	1.8	1.2	1.4	2.2	2.9	2.7	2.73	2.31	3.37
Cu	11	3	33	23	13	32	30	26	11.3	15	10.4	13	18	14
Dy	2.7	2.66	1.22	2.59	2.59	4.38	3.21	4.25	3.1	3.86	3.36	4.04	3.66	4.1
Er	1.81	1.79	0.63	1.7	1.61	2.6	1.96	2.58	2.05	2.59	2.27	3.04	2.39	2.66
Eu	0.67	0.35	0.76	0.6	0.7	0.97	0.98	1.1	0.65	0.62	0.44	0.47	0.52	0.7
Ga	15	13.08	12.51	17.25	15	17	16	15	12	13.7	12.9	10.8	14.8	14
Gd	3.18	3.37	2.61	2.91	2.62	4.13	3.66	4.62	3.08	3.65	2.81	2.88	3.31	3.84
Hf	1.33	2.16	2.12	0.94	4	3	3	5	2.4	2.9	2.4	2.5	3.4	2.8
Ho	0.82	0.95	0.68	0.79	0.55	0.91	0.73	0.93	0.61	0.83	0.73	0.93	0.77	0.86
La	12	32	30	12	21	14.5	16.3	27.2	15.3	15.8	14	9.3	16.1	15.6
Lu	0.35	0.37	0.13	0.33	0.28	0.44	0.37	0.43	0.34	0.39	0.37	0.55	0.4	0.42
Mo	<0.5	1.5	1.4	<0.5	<2	<2	2	4	0.6	0.3	0.2	<2	<2	<2
Nb	3.1	8.8	8.1	3.5	6	4	4	11	5	5.3	4	3.9	5.9	4.8
Nd	12.1	18.2	18.7	11.9	15.4	16.9	15.8	22.6	13.4	15.3	13	9.5	13.7	15.1

Sample	M4	M5	M24	M26	M2	M7	M8	M9	P2	P3	P4	R10	R11	R12
Rocks name	Andesite	Rhyolite	Dacite	Dacite	Dacite	Andesite	Andesite	Dacite	Dacite	Andesite	Andesite	Dacite	Dacite	Dacite
Ni	7	<1	25	30	<5	<5	5	<5	18	20	22	26	24	35
Pb	6	20	62	9	13.8	19	26	34	12.7	20.2	6.8	9	8	8
Pr	2.8	5.23	5.06	2.81	4.32	4.08	4.11	6.33	3.28	3.61	3.2	2.45	3.67	3.87
Rb	16	124	30	17	111	72.7	59.8	69.6	69.4	42.6	46.9	55.7	37.3	57.8
Sm	2.65	3.16	3.08	2.5	2.8	4.2	3.6	4.9	2.9	3.6	2.8	2.4	3.04	3.45
Sn	0.7	1.2	0.8	0.7	2	2	1	<1	2	2	1	1	2	1
Sr	251.9	103.2	536	198.3	380	370	410	420	1182	218.2	174.3	137	165	159
Ta	<0.1	0.34	0.23	<0.1	<0.5	<0.5	<0.5	1.2	0.4	0.4	0.4	0.3	0.5	0.4
Tb	0.32	0.32	0.2	0.31	0.4	0.72	0.58	0.74	0.53	0.65	0.57	0.55	0.57	0.64
Th	2.38	17.1	11.1	2.28	6.4	4.1	2.9	4.3	4.5	5.1	5.7	3.77	7.85	4.03
Tl	<0.1	3.18	0.35	0.1	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5
Tm	0.24	0.24	<0.1	0.22	0.26	0.42	0.33	0.4	0.31	0.43	0.36	0.49	0.36	0.4
U	0.6	3.2	3	0.5	1.77	1.03	0.64	1.17	1.4	1.5	1.3	1.25	1.41	1.2
V	110	6	71	85	45	138	140	80	102	95	83	123	95	109
W	<0.5	1.3	0.8	<0.5	1	<1	1	3	5.7	6.9	2.5	1	1	2
Y	16.6	16.2	6.4	15.5	16.5	26.1	20.3	23.8	18.9	25.6	22	26	20.3	22.8
Yb	1.9	2	1.5	1.7	1.8	2.6	2.2	2.4	2.03	2.65	2.56	3.42	2.44	2.67
Zn	54	38	210	54	61	76	62	59	15	12	13	53	41	51
Zr	65	91	148	40	119	106	89	137	79.8	88.6	70.4	63	86	76



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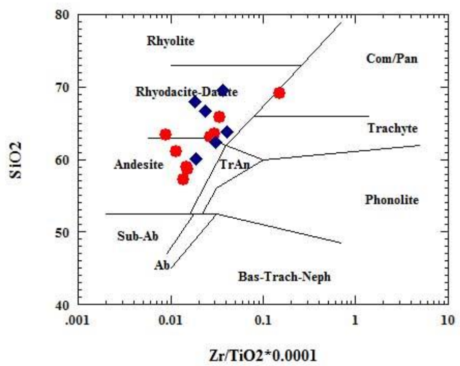


(B)

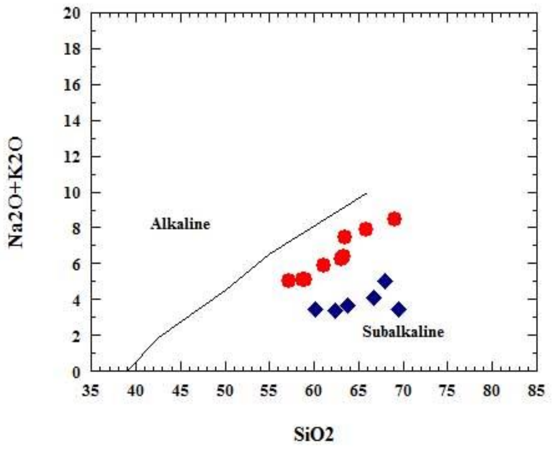
Fig. 6. Classification of magma types (A) Total alkali-silica diagram Volcanic rocks (Cox *et al.* 1979), B) SiO_2 versus $Zr/TiO_2$0.0001 (Winchester and Floyd, 1977).(◆ modified from Mehvari, 2009).

Determination of magmatic series

To determine magmatic nature of region's rocks, Irvine and Baragar's (1971) graph is used which is one of the most important graphs for determination of magmatic series. Regarding determined boundary in this graph, understudied rocks are located in the range of subalkaline (Fig. 7A). In the AFM plot (Irvine & Baragar, 1971) that distinguish between calc-alkaline and tholeiitic series, that volcanic rocks are plotted in the calc-alkaline area (Fig. 7B).

Tectonic setting

Tectonic discrimination on two diagrams (Fig 8), shows that most sample plot on the continental volcanic arc setting. Zr/Y versus Zr diagram (Ludden and Dunphy, 1998), based on rare elements. This represents a magmatic arc tectonic environment of oceanic volcanic arc environment and active continental margin volcanic arc is shared. All of the samples werelocated in the volcanic arc of active continental margins (Fig.9A). In addition, the discrimination Nb/U versus Nb diagram (Hofmann *et al.*, 1986) display a continental volcanic arc setting for these rocks (Fig.8B).



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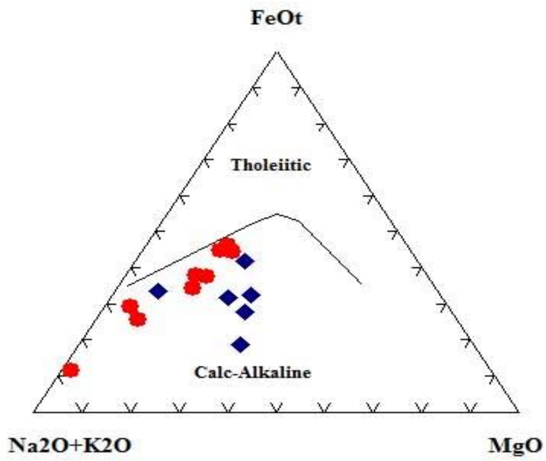
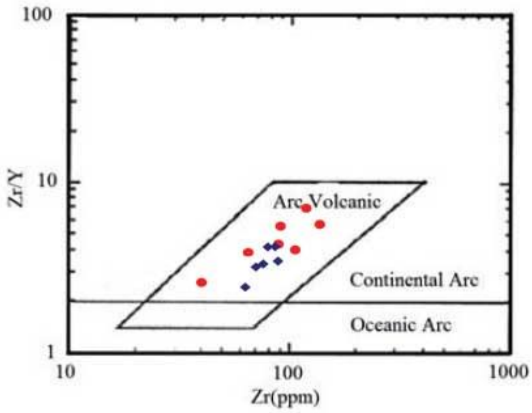


(B)

Fig. 7. Classification of the studied rocks on A) The situation of rock samples in alkaline graph of Irvine and Baragar (1971) to separate alkaline and sub alkaline series, The Volcanic samples plot in sub-alkaline field. (B) AFM (Irvine and Baragar, 1971), The Volcanic samples plot in calc-alkaline field.



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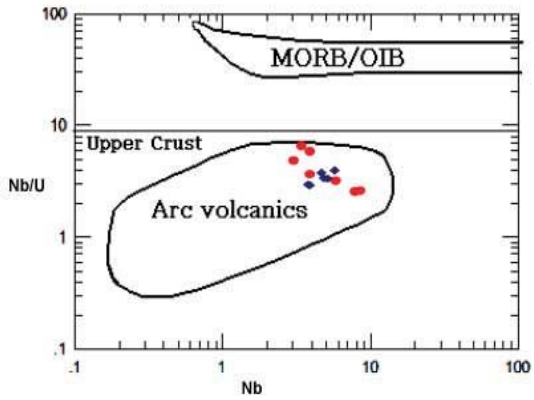


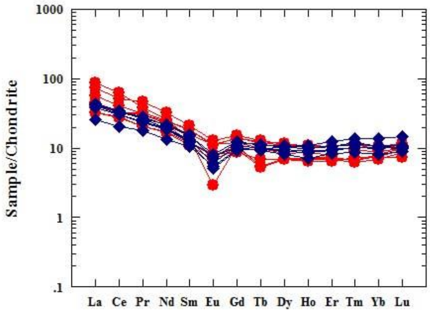
(B)

Fig. 8. Tectonic diagrams A) Zr/Y versus Zr diagram (Dunphy and Ludden, 1998), B) Nb/U versus Nb diagram (Hofmann *et al.*, 1986). All samples plotted in the volcanic arc in an active continental margin environment.

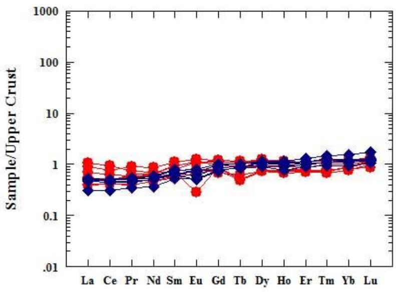
Trace and rare earth elements (REEs)

In general, the chondrite normalized REE patterns of volcanic rocks are characterized by moderate to high LREE enrichment and unfractionated HREE. This indicates the differentiation of these elements, Eu negative anomaly shows [Eu/Eu*=(0.33-0.83)]. Separation of feldspar from felsic lava rise is negative Eu anomalies (Taylor and McLennan, 1985) (Fig.9A). The volcanic rocks exhibit similar upper crust - normalized REE patterns (Fig.9 A,B). Parad*et al* (1999) suggest that the frequency of LREES enrichment may be due to partial melting or origin of these rocks are relatively rich in alkaline elements associated with subduction zones (the parad *et al.* 1999).

Sampling rocks are normalized to Chondrite and Upper Crust (Taylor and Mc Lennan, 1985) (Fig.10A, B). Rocks are enriched in LILE (e.g., Ba and Th), relatively depleted in HFSE (e.g., Ni, Cr). Well-defined negative anomaly is observed for Ni. Fractionation or presences of some minerals in the restates explain the negative anomalies, for example, olivine (Ni,Cr). The volcanic rocks exhibit similar Upper Crust -normalized Spider patterns.

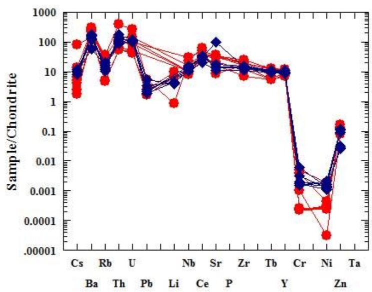


(A)

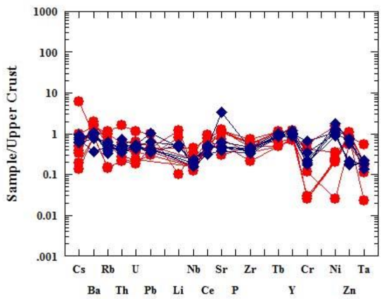


(B)

Fig. 9. A) Chondrite-normalized REE pattern for metabasite rocks. (B) The volcanic rocks normalized with Upper Crust, Normalization data from (Taylor andMcLennan, 1985).



(A)



(B)

Fig.10. Plate trace elements pattern. (A) Chondrite-normalized, (B) Upper Crust (normalized data from (Taylor andMc Lennan, 1985).

Conclusion

Eocenevolcanic rocks, in the middle part of the Central Iranian Volcanic Belt (Urumieh-Dokhtar Magmatic Arc) these rocks show dacite to andesite composition. Andesite include phenocrysts of plagioclase, pyroxeneand amphibole with a prevailing porphyritic texture in a matrix composing of feldspar, quartz, microlite and glass. In some cases, plagioclases are strongly altered to epidote, chlorite and calcite. Mineral assemblage in daciteis quartz, amphibole and plagioclases (phenocryst) and quartz, feldspar and microlitic plagioclase. Accessory minerals in these rocks arecaly and opaque mineral. In the distinguish diagrams, volcanic rocks are plotted in the sub-alkaline area and calc-alkaline series. In the REE and trace elements spider diagram, these similar to upper crust. Enrichment in LILE and depletion of HFSE in the studied rocks as well as various petrologic diagrams point to magmatism in arc of an active continental margin.

References

Aftabi A, Atapour H. 2000. Regional aspects of shoshonitic volcanism in Iran. Episodes **23(2),** 119-125.

Agard P, Omrani J, Jolivet L, Whitechurch H, Vrielynck B, Spakman W, Monie P, Meyer B, and Wortel R. 2011. Zagros orogeny: a subduction-dominated process. In: Geodynamic Evolution of the Zagros (Eds. Lacombe, O., Grasemann, B. and Simpson, G.). Geological Magazine 692-725.

Allen M, Jackson J, Walker R. 2004. Late Cenozoic reorganizatoin of the Arabia-Eurasia collision and comparison of short-term and long-term deformation rates. Tectonics **23,** 1-16.

Amidi SM, Emami MH, Michel R. 1984. Alkaline character of Eocene volcanism in the middle part of Central Iran and its geodynamic situation. Geologische Rundschau **73,** 917-932.

Amini B, Amini Chehragh MR. 2003. 1:100000 Geological map of Kajan. Geological survey and mineral explorations of Iran.

Cox KG, Bell JD, Pankhurst RJ. 1979. The interpretation of igneous rocks. George, Allen and Unwin 45p.

Dewey DE, Hempton MR, Kidd WSF, Saroglu F, Sengo AWC. 1986. Shortening of continental lithosphere: The neotectonics of Eastern Anatolia- a young collision zone, In. coward, M.P., Ries, A.C., (Eds), collision zone Tectonics, Geological society of London Special Publication **19,** 3-36.

Dewey JF, Pitman WC, Ryan WB, Bonnin J. 1973. Plate tectonics and the evolution of the Alpine system. Geol Soc Am Bull **84,**3137–3180

Dilek Y, Imamverdiyev N, Altunkaynak S. 2010. Geochemistry and tectonics of Cenozoic volcanism in the Lesser Caucasus (Azerbaijan) and the part-Arabian region: collision- induced mantle dynamics and its magmatic fingerprint-International Geology Review **52,** 536-578.

Dilek Y, Sanduol E. 2009. Seismic structure, crustal architecture and tectonic evolution of the Anatolian-African plate boundary and the Cenozoic organic belts in the eastern Mediterranean region. Geological society ofLondon special publication **327,** 127-160

Dilek Y, Whitney DL. 2000. Cenozoic crustal evolution in central Anatolia: Extension, magmatism and landscape development. Proceedings of the Third International Conference on the Geology of the Eastern Mediterranean, Geological Survey Department, September 1998, Nicosia-Cyprus 183–192.

Dimitrijevic MD. 1973. Geology of Kerman region. Geological Survey of Iran, Tehran.

Dunphy JM, Ludden JN. 1998. Petrological and geochemical characteristics of a Paleoproterozoic magmatic arc (Narsajuaq terrane, Ungava, Canada) and compositions to Superior Province granitoids. Precambrian Research **91,** 109-152.

Emami MH. 1981. Geologie de la region de Qom-Aran(Iran).Contribution a letude dynamique et geochimique du volcanisme tertiaire de Iran central. These doctrat d Etat, Grenoble, 489p.

Emami MH. 2000. Magmatism in Iran. Geological Survey of Iran, Tehran.

Farahoudi G. 1978. A comparison of Zagros geology to island arcs. J Geol **86,** 323–334.

Hassanzadeh J. 1993. Metallogenic and tectonomagmatic events in the SE sector of Cenozoic active continental margin of Central Iran (Shahre-babak area), Kerman province. PhD thesis, University of California, Los Angeles, USA.

Hessami K, Jamali F, Tabassi H. 2003. Map of major active faults of Iran, scale 1:2500000, International Institute of Earthquake Engineering and Seismology, Tehran.

Hofmann AW, Jochum KP, Seufert M, White WM. 1986. Nb and Pb in oceanic basalts: new constraints on mantle evolution. Earth and Planetary Science Letters **79,** 33-45.

Irvine TN, Baragar WRA. 1971. A guide to chemical classification of common volcanic rocks., Canadian Journal of Earth Sciences **8,** 523-547.

Jackson J, McKenzie D. 1984. Active tectonics of the Alpine-Himalayan belt between western turkey and Pakistan. Geophysical Journal International **77,** 185-264.

Mc Clusky S, Reilinger R, Mohmoud S, Bensari D, Tealeb A. 2003. Gpseonstrains on Africa (Nubia) and Arabia plate motion. Geophysical Journal International **155**, 126-138.

Mehvari R. 2009. Petrological and mineralogical studies of the hydrothermal alteration (bentonization and silicification), molla ahmad stighiu (east of Isfahan). MSc thesis, University of Isfahan, Isfahan, Iran (in Persian).

MoClusky S, Balassanian S, Barka A, Demir G, Ergintav S, Georgiev G, Gurkan D, Hamburger M, Hurst K, Kahle H, Kastens K, Kekelidze G, King R, Kotzev V, Lenk O, Mohmoud S, Mishin A, Ndariy M, Ouzounis A, Paradissis D, Peter Y, Prilepin M, Reilinger R, Sanli Z, Seeger H, Tealeb A, Toksoz MN, Veis G. 2000. Global positioning system constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus. Journal of Geophysical Research **105,** 5695-5719.

Parad MA, Nystrom JO, Levi B. 1999. Multiple source for the Coastal Batholith of Central Chile, geochemical an Sr-Nd isotopic evidence and tectonic implication. Lithos **46,** 505-521.

Rutherford MJ. 1993. Experimental petrology applied to volcanic processes. American Geophysical Union **74,** 49-52.

Sayari M. 2015. Petrogenesis and evolution of Oligocene- Pliocene volcanism in the central part of Urumieh-Dokhtar Magmatic Arc (NE of Isfahan).Phd thesis, University of Isfahan, Isfahan, Iran (in Persian).

Shahabpour J. 2005. Tectonic evolution of the orogenic belt in the region located between Kerman and Neyriz. J Asian Earth Sci **24,** 405–417.

Taylor SR, McLennan SM. 1985. The Continental Crust: its Composition and Evolution. Blackwell, Cambridge. 312 p.

Winchester JA, Floyd PA. 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology **20,** 325–343.