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Petrology and Geochemistry of Volcanic Rocks in North Khur, Northwestern Birjand

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Abstract: The study volcanic complex is located in southern khorasan province, in 90 km of northwest of Birjand and in North of Khour. The study volcanic rocks are including Basaltic andesite andesite and trachyandesite, Latite, Dacite to Rhyodacite and pyroclastic rocks are including Tuff and breccia. The essential and common minerals of these rocks are plagioclase, clinopyroxene, hornblende, biotote and quartz and minor and alteration minerals of these rocks are clay minerals, sericite, calcite, chlorite, epidote and secondary quartz. The majority texture of these rocks is porphyry. Magmatic series of most samples are calc alkaline but some samles have inclination to tholleitic serie. Positive abnormality of Pb is showing alteration of mantle wedge by fluids which have originated from sinking oceanic crust and or from magma contamination with continental crust. Enrichment of samples from Ba and Sr also are related to fluids which are derivated from water bearing sediments and also separation and moving of these fluids from oceanic crust to mantle wedge. Negative abnormality of P, Nb and Ti elements which has caused multiplication pattern in rare elements changing trend in samples, can show formation of rocks in subduction area. Tectonic definition diagrams are showing that andesitic basalts of area are situating in field of calc alkaline basalts of volcanic arc. Furthermore in diagram of magmatic arc definition, the study rocks are situating in field of continental arc and seems which magmatism of area has been result of subduction of a oceanic crust under the continental crust (Lut block).

Key words: Volcanic rocks, North of Khur, calc alkaline, oceanic crust, subduction, Lut block

INTRODUCTION

Volcanic assemblage of north Khur in South Khorasan Province is located at a distance of 90 km northwest of Birjand at a longitude range from 58°26'36" - 58°41'49" and a latitude range from 33°02'78" to 33°14'66" (Fig. 1). This region is a part of the Geological map of Sarqeng (Scale 1: 100,000) and is considered as a part of Lut block with regard to tectono-sedimentary divisions. The present study was aimed at petrology and geochemistry of volcanic rocks in north Khur and determining crystallization tectonic environment of these rocks. The volcanic rocks under investigation were andesite basalt andesite and trachyandesite, latite, dacite to rhyodacite and pyroclastic rocks including tuffs and volcanic cuttings.

Geology of the study region: Many geologists believe that volcanic rocks of north Khur are related to subduction in east of Iran. In this regard, Camp and Griffis (1982) related the formation of rift and creation of eastern block (the Afghan block) and western block (Lut block) to the middle Cretaceous. By determining isotopic age, Rad *et al*. (2005) related the emergence of rifts to the end of the Jurassic. Camp and Griffis (1982) believe that replacement and displacement of ophiolites inside flysches in the end of the Cretaceous caused slight metamorphism in flysches which was associated with underthrusting of oceanic crust beneath Afghan block. However, Camp and Griffis (1982) and Rad *et al.* (2009) related replacement and displacement of ophiolites inside flysches to the early Cretaceous and believed that moderate to severe metamorphism occurred in the region. After Lut block and flysch zone met and collided in Middle Eocene, calc alkaline volcanoes as old as Paleocene and Lower Eocene formed as a result of partial melting of the oceanic crust and after the two blocks collided, subduction ended in Paleogene (Camp and Griffis, 1982). Following the pressure phase of Late Cretaceous which was associated with metamorphism, folding and uplift of ophiolites, an important extension phase dominated all over Iran except for Zagros and Kopet Dagh which led to intense volcanism of Eocene (Zarrinkoub *et al*., 2011; Imami, 2000). This volcanism can extensively be seen in the east of Iran (Zarrinkoub *et al*., 2011).

As mentioned before, a large part of the study region is composed of Middle Eocene to Upper Oligocene

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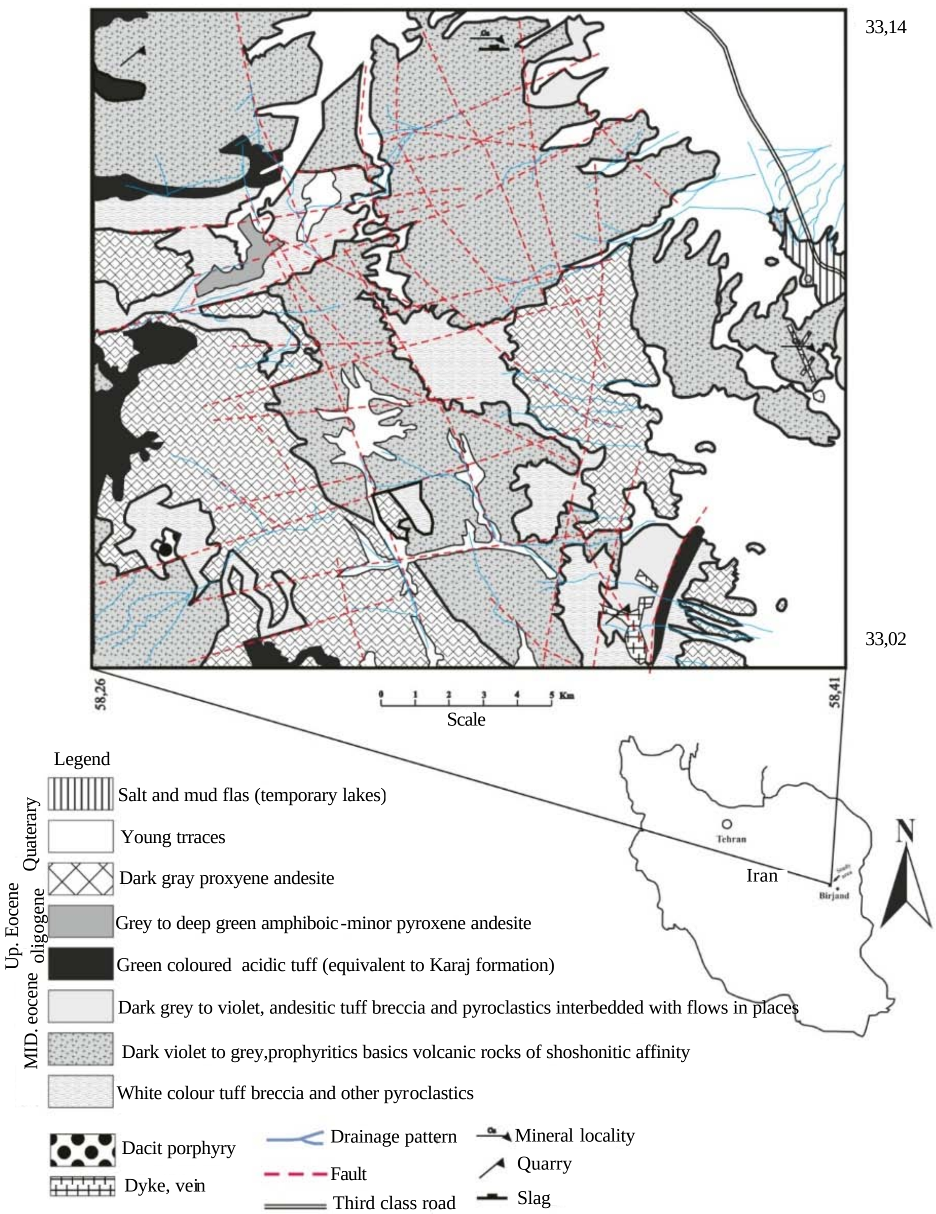

Fig. 1: The geological map of North Khur (Scale 1:50,000) (Adapted from geological map Sarqeng)

volcanic rocks which are considered equal to Karaj Formation in Iran's stratigraphy. However, it should be noted that according to the Geological map of Sarqeng (Scale 1: 100,000), the volcanic rocks of Karaj Formation as old as the Middle Eocene in the target region have less developed and can only be seen in some parts. Nevertheless, lithology separated on this map in this region which is considered different from Karaj Formation is to some extent seem to be a part of this formation. In continuation, it should be referred to that except for the mentioned volcanic rocks in this region, there are other outcrops of volcanic rocks as old as Upper-Oligocene Eocene which possess thinner composition compared to Eocene volcanic rocks.

MATERIALS AND METHODS

Petrography: According to the conducted field and laboratory examinations, the studied volcanic rock included andesite basalt andesite and trachyandesite, latite, dacite to rhyodacite and pyroclastic rocks including tuffs and volcanic cuttings. After placing in the above

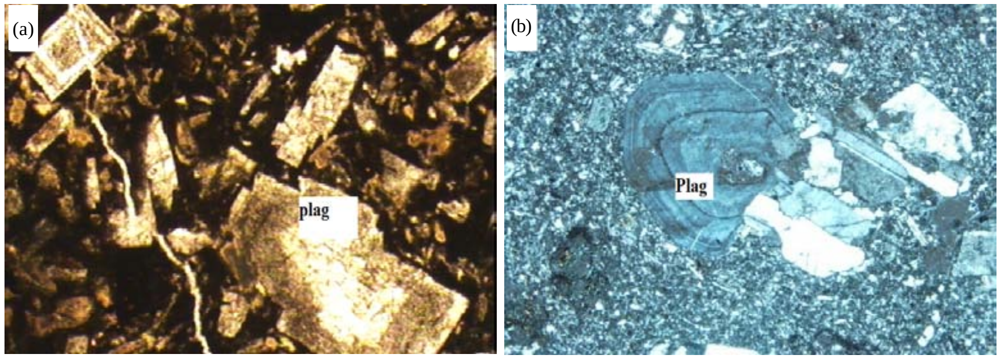

Fig. 2: A) Reactive margins of plagioclases in the crystal background of andesite which is an indication for magma mixing (XPL); B) Zoning in plagioclase in the felsic background of a rhyodacite (XPL)

volcanic assemblages andesitic dykes crystalize and meanwhile they alter the surrounding rocks.

In the field, this volcanic assemblage is characterized by a greenish gray color and a fine-grained to porphyritic making. The mentioned rocks are more influenced by sericitic and argillic alteration and their minerals have mostly turned into sericitic and clay minerals. However, it should be noted that these rocks have also been affected by other alterations including propylitic, siliceous and zeolite alterations which have a secondary importance. The formed minerals of these rocks include.

Plagioclase: In microscopic sections, plagioclase phenocrysts are the most abundant minerals existing in these rocks and porphyritic andesites form more than 60% of the volume percentage of the rock. The size of phenocrysts varies between 0.5-2 mm and are mostly characterized by a mass with fine, porphyritic, vitrophyric and orthophyric textures. Presence of zoning in plagioclases indicates a decrease in oxygen fugacity due to the existence of hornblende and biotite in the samples. Andesite, sericite, clay minerals, calcite and epidote are created as a result of alteration of plagioclases and iron oxide can be observed on the surface of some of them. As reported by other researchers (Dungan and Rhodes, 1978; Kawamoto, 1992; Pecerillo and Taylor, 1976; Halsor, 1989; Eichelberger, 1978; Tsuchiyama, 1985), severe liquidation and corrosion and reactive margins can be seen in some plagioclases. Stewart and Pearce (2004) consider this evidence as a reason for magma mixing (AFC) in magma forming the rocks and believe that instability of plagioclases while moving upward is due to the emergence of sieve texture in them, because some parts of plagioclases partially melt and the products caused by plagioclases melting start to crystalize inside the crystals (Fig. 2a). Depending on the slowness or fastness of temperature decrease rate, these products crystalize in the form of glass or new plagioclase inside the primary crystalized plagioclase and lead to emergence of this texture (Fig. 2a and b).

Biotite and hornblende: These minerals account for 5-20 volume percent of the studied rocks. Hornblende mineral is more abundant than biotite and exists in both self-shaped and semi-self-shaped forms in cross sections and is mostly seen in andesites and andesite basalts. Most of these minerals are located in the burnt margin and have turned into iron oxides and opaque minerals and in central parts into chlorite. Observing burning in hydrous minerals of biotite and hornblende indicates high level of PH_2O in the end of crystallization history and high level of oxygen fugacity during lava outflow (Best and Christiansen, 2001; Hess, 1989). Others attributed this issue to a decrease in pressure as a result of magma approaching to the earth surface, magmatic gas emissions and an increase in cooling speed and magmatic adhesion which is called opacity margin (Shalley, 1993; Rittmann, 1973) (Fig. 3b).

Pyroxenes: Pyroxenes, including both clinopyroxene and orthopyroxene are also observed as phenocrysts and fine-grained such that these minerals account for 10 volume percent of the rocks in andesite pyroxene. The effects of magma mixing can also be seen in them in addition to plagioclases (Fig. 3a).

Magnetite: As the opaque and secondary mineral, magnetite forms about 1-5 volume percent of the sample and is seen in fine- to coarse-grained and amorphous form inside andesites and trachyandesites.

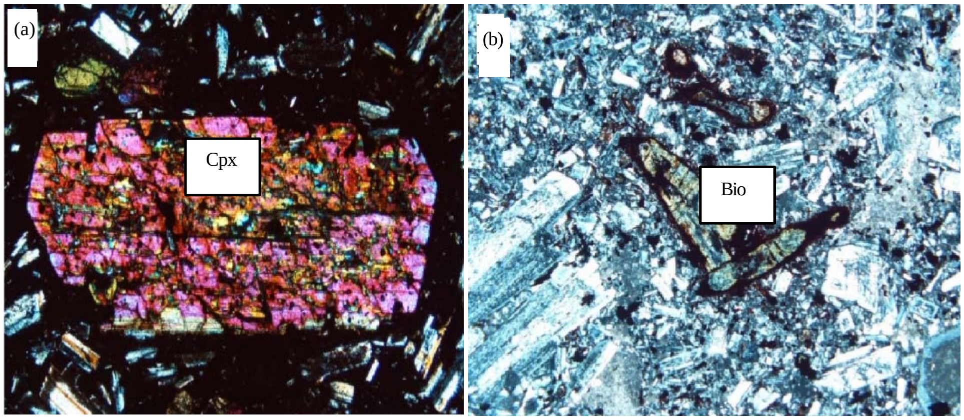

Fig 3: a) Formation of sieve texture in clinopyroxene and its conversion into chlorite in an andersite basalt (XPL); b) Biotites with burnt margin in latite (XPL)

Table 1: The results of chemical analysis of the selected samples in north Khur by XRF method

Rows name	KH-1	KH-2	KH-3	KH-9	KH-10	KH-18	KH-23	KH-30	KH-50	KH-52	KH-53	KH-56	KH-58
SiO_2(Wt%)	63.91	47.1	63.74	53.47	58.95	65.83	58.47	62.61	61.01	43.65	66.94	62.63	64.27
Al_2O_3	15.12	8.17	14.29	13.06	13.78	14.21	13.5	13.22	15.05	11.1	14.15	14.3	14.55
Fe_2O_3	5.59	1.96	6	9.07	8.79	5.52	7.98	7.57	8.71	9.48	5.84	8	4.71
CaO	5.7	1.07	4.34	7.8	8.79	5.68	6.36	0.24	4.96	15.79	3.6	5.73	5.43
Na_2O	3.29	0.01	3.07	2.71	1.87	2.62	2.02	0.01	1.91	2.62	2.92	1.88	2.94
K_2O	0.75	0.08	3.31	3.19	2.46	2.26	3.02	0.18	3.27	3.11	3.24	3.14	2.24
MgO	1.6	0.06	1.43	2.71	3.66	0.57	1.81	0.03	1.06	2.2	0.15	0.48	2.27
TiO_2	0.964	0.218	0.995	0.495	0.983	0.533	1.986	0.647	1.98	1.014	1.116	1.17	0.525
MnO	0.411	0.013	0.107	0.104	0.126	0.104	0.094	0.007	0.091	0.51	0.088	0.09	0.091
P_2O_5	0.519	0.879	0.137	0.129	0.199	0.188	0.649	0.311	0.418	0.295	0.367	0.427	0.134
SO_3	0.003	1.489	0.003	0.003	0.065	0.08	0.003	0.62	0.003	0.003	0.003	0.013	0.103
LOI	2.68	8.65	1.98	6.25	1.93	2.01	3.73	6.33	2.03	9.9	1.2	2.11	2.49
Cl(ppm)	92	71	180	144	201	269	117	4177	7	338	13	76	197
Ba	716	549	759	629	690	752	851	14801	830	628	765	775	1181
Sr	464	482	406	839	503	365	335	860	370	921	339	383	729
Cu	98	260	120	163	99	73	183	476	21	147	27	91	110
Zn	49	129	56	48	65	31	79	26	75	58	94	69	38
Pb	17	3	19	12	11	15	18	73	16	18	14	14	11
Ni	12	1	7	25	45	6	13	4	12	26	3	21	25
Cr	18	10	19	65	174	14	28	33	34	106	55	59	28
V	114	120	138	229	196	81	276	197	162	227	240	255	86
Ce	2	36	52	49	28	3	124	82	48	72	54	98	41
La	1	51	15	23	13	1	43	35	34	42	30	29	18
W	1	1	1	1	1	1	1	1	1	1	1	1	366
Mo	1	1	1	1	1	1	1	1	1	1	1	1	1
Nb	2	2	1	3	2	1	2	3	1	1	2	2	1
Zr	160	120	283	191	189	125	359	209	209	208	154	186	150
Y	2	2	14	9	7	3	29	2	11	17	3	9	5
Rb	28	1	18	67	71	58	80	23	88	76	55	73	45
Co	17	2	16	27	22	16	26	18	17	25	15	18	15
As	38	70	55	55	40	38	60	358	50	104	51	55	50
U	1	1	1	1	1	1	1	1	1	1	1	1	1
Th	1	1	1	1	1	1	1	1	1	1	1	1	1

Quartz: This mineral does not exist in andesites at all or accounts for less than 5 volume percent of the minerals. It is more in fine-grained and sometimes coarse-grained form and forms about 10% of the rock in dacites. This mineral is observed both as vein-veinlet and in secondary form (Fig. 4).

Secondary minerals: Minerals such as sericite, clay minerals, calcite, chlorite, epidote and secondary quartz are observed in this group of rocks which are caused by alteration of minerals such as plagioclase, pyroxene, hornblende and biotite. Fine-grained quartz in tuffs are caused as a result of devitrification of fused glasses of background rock. As other secondary minerals, zeolites fill the space between the cracks and fractures.

Background and texture: The background of these rocks is composed of fine microliters, glass, plagioclase,

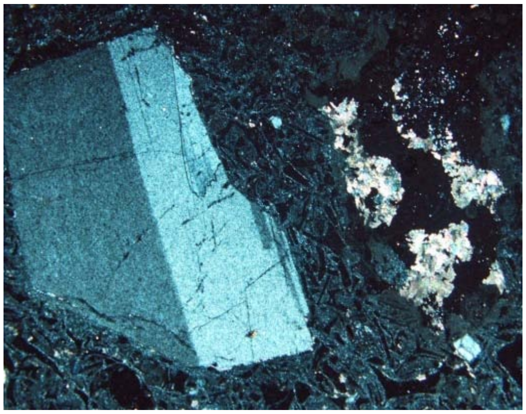

Fig. 4: Conversion of glasses into quartz crystals in rock background and filling up the pores by them in tuffs (XPL)

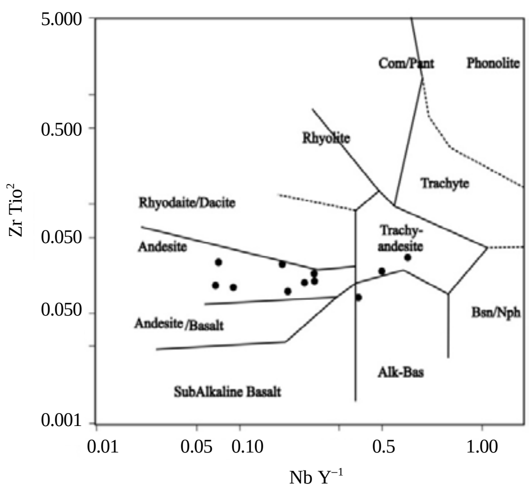

Fig. 5: The position of volcanic rocks in north Khur in the diagram proposed by Winchester and Floyd (1977)

sanidine and sporadically clay minerals that flow in trachyandesites, fine plagioclase and sanidine. In some cases, background rocks contain iron oxides and are brown. Other textures include vitrophyr orthophyr, glomeroporhyry, intergranular and spherolitite. Sieve textures, soluble textures and reactive margins were referred to previously as evidence for magma mixing.

Geochemistry and petrogenesis: Due to the almost extensive alteration of volcanic rock in the region and genesis of secondary minerals, there was an attempt to carry out geochemical examinations on intact and less altered samples. The results of geochemical analysis of volcanic rocks are presented in Table 1.

Since the possibility of alteration and mineralogical and chemical changes in volcanic rocks is high, other components that have less possibility of displacement are used for more precise naming. Therefore, the diagram proposed by Winchester and Floyd (1977) was employed to name the rocks (Fig. 5). The SiO_2 amount of these rocks varies between 43 and 67% and their Al_2O_3 amount is as high as about 15%. High amount of Al_2O_3 in basalts indicates crystallization of mafic minerals from their primary melted producers in relatively high pressures (Gust and Perfit, 1987; Yoder and Tilley, 1962) which leads to concentration of aluminum in the remaining melted minerals and results in crystallization of plagioclase in lo pressures (Table 2).

According to AFM diagram (Irvine and Baragar, 1971), most samples are placed in magmatic series of calc alkaline which are inclined toward tholeitic series (Fig. 6). Variation range of K_2O is these rocks is relatively extensive (0.08-3.31) and most samples place in high-potassium calc alkaline series (Morata and Aguirre, 2003) (Fig. 7). Diversity and dispersion of samples in terms of the amount of K_2O can be as a result of the mobility of potassium during the alteration process of the region's rocks. Figure 8 presents the changes in elements TiO_2, FeO and MgO in relation to SiO_2 (Harker, 1909) whose amount declines with an increase in the amount of SiO_2 (particularly in the two samples KH9 and KH10) which shows the partial crystallization of clinopyroxene mineral during magmatic crystallization. Moreover, the relation between CaO and SIO_2 amounts is almost like this and can depend on the formation of plagioclases from calcic to sodic.

As mentioned in the two basaltic andesite samples, pyroxene crystals can be seen in coarse-grained microscopic sections which results in high amounts of MgO in these samples compared to other ones. Moreover, the amounts of chrome, cobalt and nickel are high in these two samples which indicates intense tendency to separate from magma in the beginning of magmatic differentiation (Norman and Leeman, 1991). Among rare elements, compatible elements like chrome, nickel and vanadium have an almost declining trend compared to SiO_2. In the beginning of the separation trend, these elements separate from basaltic magma and enter pyroxene and magnetic minerals (Mason and Moore, 1982).

Figure 9, the chemical composition of the region's volcanic rocks is normalized compared to the primitive mantle (Sun and McDonough, 1989). In this diagram, elements Pb, K, Ba and Sr have a positive abnormality in all samples. They are mobile and LILE (low-ion lithophile elements) elements whose concentration is a function of fluid phase. However, elements Nb, Rb and Ce have negative normality in all sample and are inactive and HFSE (large-ion lithophile elements) elements whose

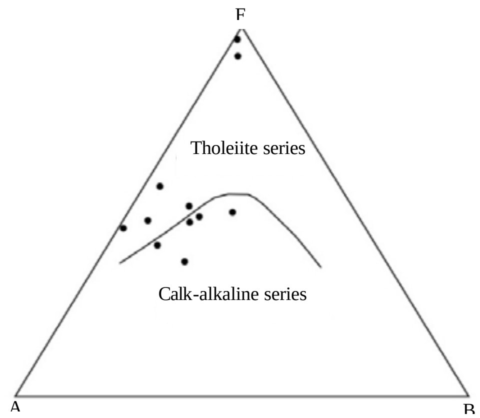

Fig. 6: AFM diagram for determining magmatic series of the rocks of north Khur (Irvine and Baragar, 1971)

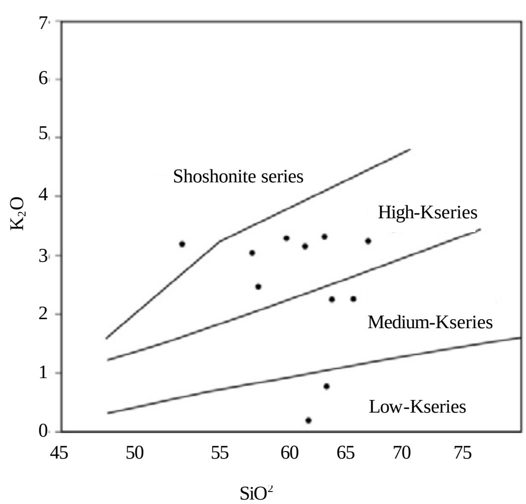

Fig. 7: SO2 diagram relative to K2O to determine magmatic series of volcanic rocks in north Khur (Morata and Aguirre, 2003)

concentration is controlled with chemistry of source rock and crystalizing-melting process during the rock formation (Rollinson, 1993). Moreover, elements Ti, P and Zr have negative normality in some samples.

Due to having low ionic potential, LILE elements dissolve and transfer easily in hydrous fluids in low pressure and high temperature (Tatsumi and Eggins, 1995; Ryerson and Watson, 1987; Green and Pearson, 1986) while solubility of HFSE elements in hydrous fluids is low (Tatsumi *et al*., 1986). Therefore, mantle wedge is enriched from LILE elements to HFSE ones by losing the water of subducted oceanic crust during partial melting (Green, 2006). Lavas of subduction zone are usually characterized by depletion of HFSE elements relative to LILE ones. The reason for this depletion can be the effect of fluids or melting materials resulted from the subducted plate on the mantle wedge (Green, 2006). During magmatism of subduction zone, hydrous fluids are responsible for transferring some incompatible elements from the subducted crust to continental crust in Sagittarius (Hermann *et al*., 2006). High proportion of LILE/HFSE in Sagittarius rocks is the result of entry of LILE elements existing in subducted plate into the above mantle wedge (Mohamed *et al*., 2000). Moreover, subduction process plays an effective role in an increase in the proportion of LILE/HFSE (Hole *et al*., 1984; Saunders *et al*., 1980).

Positive abnormalities of Pb are caused by the metasomatism of mantle wedge through fluids resulted from subducted oceanic crust or assimilation of magma with continental crust. Enrichment of samples with Ba and Sr is caused by the fluids derived from hydrous deposits and also their separation and transfer from the oceanic crust to mantle wedge (Kamber *et al*., 2002). Negative abnormality of elements P, Nb and Ti, causing the formation of crisscross pattern in the trend of changes in rare elements in the samples, indicates the formation of rocks in the subducted region because subduction of the fluids that are released from subducted lithosphere and are poorer than Nb and richer than LILE increases (Pearce and Parkinson, 1993).

Low amount of chrome in some volcanic rocks is a function of the different amount of mantle melting or separation of crystalline. Moreover, the amount of yttrium in island arc basalts has emptied compared to other types of basalt (Rollinson, 1993). The amount of chrome in the region's rocks varies from 10-1,774 ppm and the extensive range of this element in volcanic arc basalt rocks is effectively caused by the presence of ferromagnesian minerals. In the diagram proposed by Pearce (1982), the studied rock are placed in the range of volcanic arc basalt rocks (Fig. 10). In order to carry out a more precise examination on the tectonic environment of the region's rocks, the diagrams proposed by Mullen (1983) and Pearce and Cann (1973) were also employed which indicated that the region's rocks are categorized within the range of calc alkaline basalts and in relationship with volcanic arc (Fig. 11).

In order to recognize the magmatic arc of active continental margin from magmatic arc of oceanic island, the diagram proposed by Pearce (1983) was employed (Fig. 12). It was observed that the studied rocks

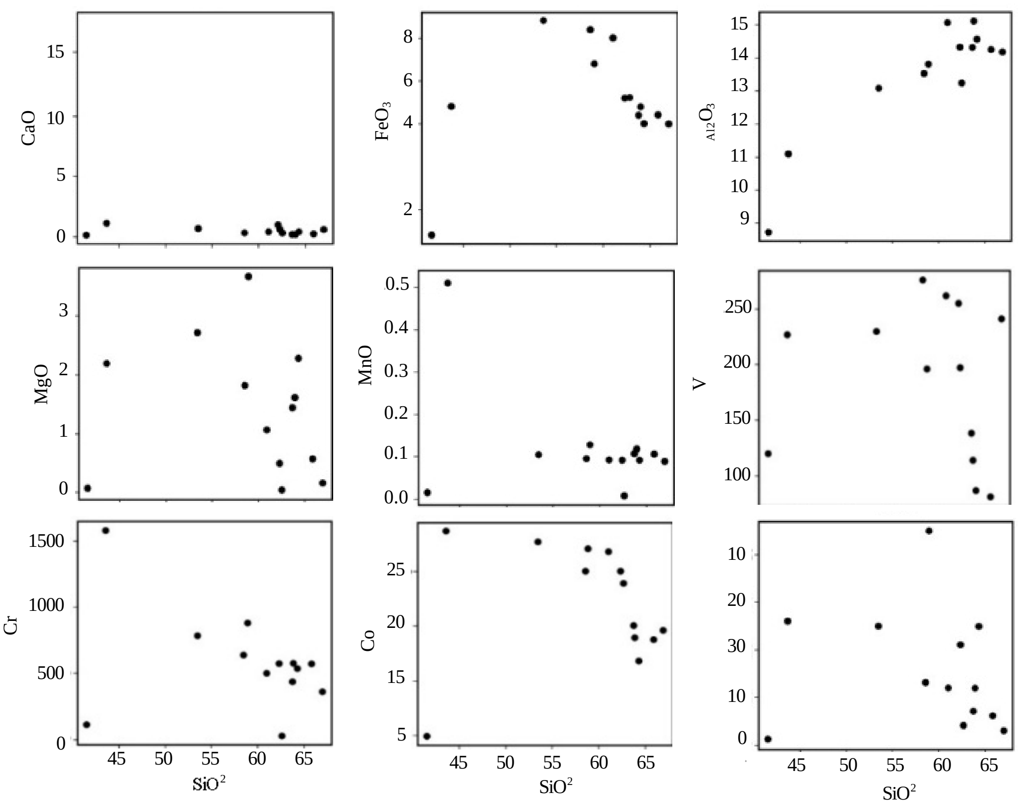

Fig. 8: The trend of changes in main and secondary elements relative to SiO2 in Harker (1909)'s diagrams

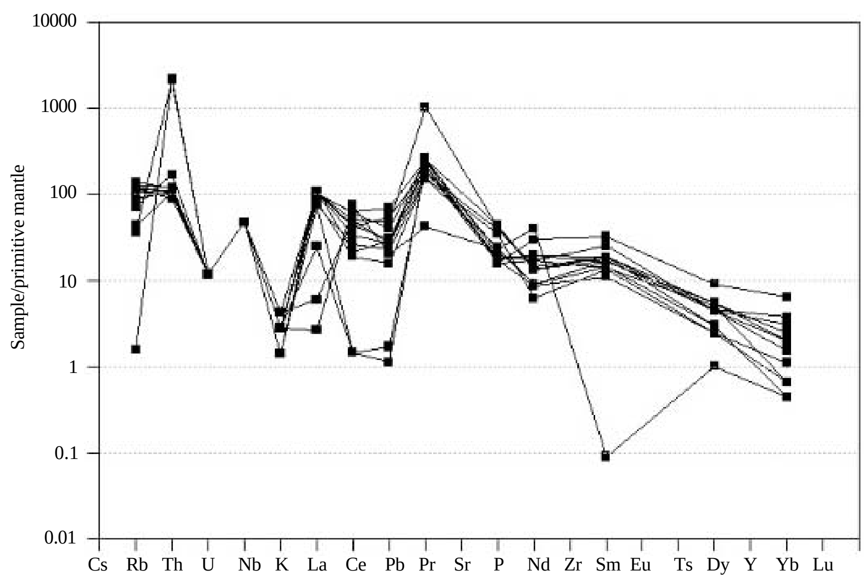

Fig. 9: Spider diagram of volcanic rocks in north Khur, normalized relative to the primitive mantle (Winchester and Floyd, 1977)

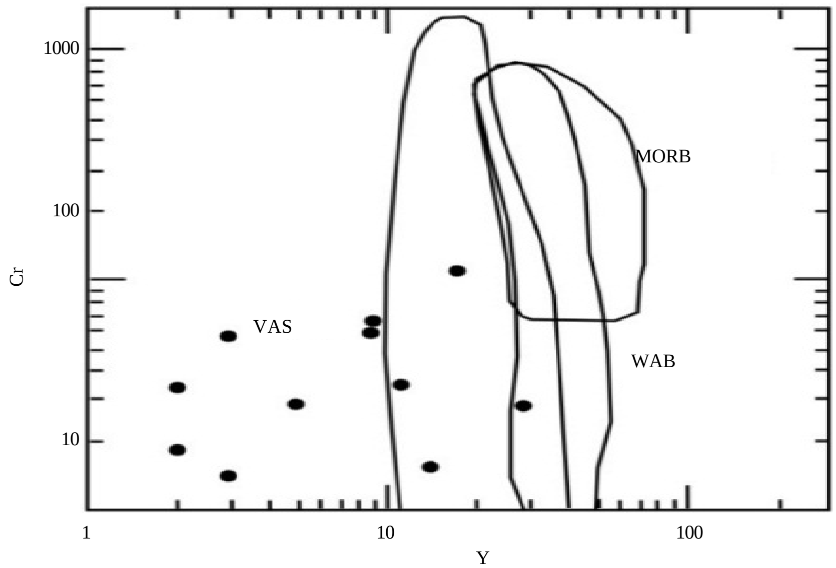

Fig. 10: Determining the tectonic environment of the volcanic rocks in North Khur in Cr-Y diagram (Pearce, 1982), MORB basalts (MORB) within-plate basalts (WAB), volcanic arc basalts (VAB)

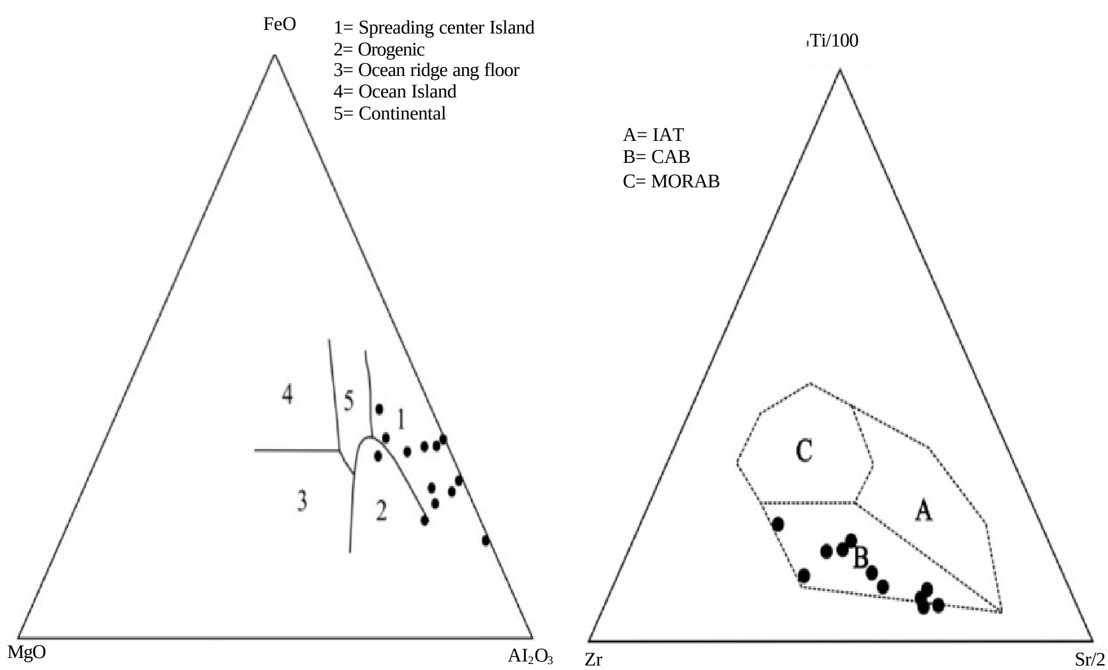

Fig. 11: Determining tectonic environment of the volcanic rocks in North Khur in the diagrams proposed by Mullen (1983) and Pearce and Cann (1973)

are placed in the range of continental arc and it seems that magmatic arc forming the region's rocks has been caused by the subduction of an oceanic crust beneath a continental crust. The Zr/Y proportion can be used to recognize magmatic arc such that if this proportion is over 3, the arc is continental and otherwise, it is oceanic (Pearce and Norry, 1979).

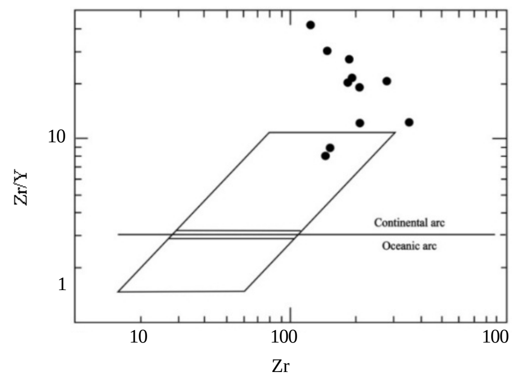

Fig. 12: Diagram of determining tectonic environment of the volcanic rocks in north Khur based on variations in Zr relative to Zr Y^{-1} (Pearce, 1983)

CONCLUSION

The studied volcanic rocks included andesite basalt andesite and trachyandesite, latite, dacite to rhyodacite and pyroclastic rocks including tuffs and volcanic cuttings. Plagioclase, clinopyroxene, hornblende, biotite and quartz are the main and common minerals and sericite, clay minerals, calcite, chlorite, epidote and secondary quartz are secondary and metamorphic minerals.

The dominant texture of these rocks in porphyr. Other textures include vitrophyr orthophyr, glomeroporhyry, intergranular and spherolitite. The magmatic series of the studied rocks is calc alkaline series and some of them are inclined toward tholeitic series. Variation range of K_2O is these rocks is relatively extensive (0.08-3.31) and most samples place in high-potassium calc alkaline series.

Positive abnormalities of Pb are caused by the metasomatism of mantle wedge through fluids resulted from subducted oceanic crust or assimilation of magma with continental crust. Enrichment of samples with Ba and Sr is caused by the fluids derived from hydrous deposits and also their separation and transfer from the oceanic crust to mantle wedge. Negative abnormality of elements P, Nb and Ti, causing the formation of crisscross pattern in the trend of changes in rare elements in the samples, indicates the formation of rocks in the subducted region, because subduction of the fluids that are released from subducted lithosphere and are poorer than Nb and richer than LILE increases.

In the diagrams of determining tectonic environment, the region's basaltic andesite rocks are placed within the range of calc alkaline basalts and in relation with volcanic arc. In the diagram of determining the type of the magmatic arc, the studied rocks are counted in the range continental arc and it seems that the magmatic arc forming the region's rocks is resulted from the subduction of an oceanic crust beneath a continental crust.

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REFERENCES

Best, M.G. and E.H. Christiansen, 2001. Igneous Petrology. Wiley-Blackwell, Hoboken, New Jersey, Pages: 485.

Camp, V. and R. Griffis, 1982. Character, genesis and tectonic setting of igneous rocks in the Sistan suture zone, eastern Iran. Lithous, 15: 221-239.

Dungan, M.A. and J.M. Rhodes, 1978. Residual glasses and melt inclusions in basalts from DSDP Legs 45 and 46: Evidence for magma mixing. Contrib. Miner. Petrol., 67: 417-431.

Eichelberger, J.C., 1978. Andesites in island arcs and continental margins: Relationship to crustal evolution. Bull. Volcanol., 41: 480-500.

Green, N.L., 2006. Influence of slab thermal structure on basalt source regions and melting conditions: REE and HFSE constraints from the Garibaldi volcanic belt, northern Cascadia subduction system. Lithos, 87: 23-49.

Green, T.H. and N.J. Pearson, 1986. Ti-rich accessory phase saturation in hydrous mafic-felsic compositions at high P, T. Chem. Geol., 54: 185-201.

Gust, D.A. and M.R. Perfit, 1987. Phase relations of a high-Mg basalt from the Aleutian Island Arc: Implications for primary Island arc basalts and high-Al basalts. Contrib. Mineral. Petrol., 97: 7-18.

Halsor, S.P., 1989. Large glass inclusions in plagioclase phenocrysts and their bearing on the origin of mixed andesitic lavas at Toliman Volcano, Guatemala. Bull. Volcanol., 51: 271-280.

Harker, A., 1909. The Natural History of Igneous Rocks. Macmillan, New York.

Hermann, J., C. Spandler, A. Hack and A.V. Korsakov, 2006. Aqueous fluids and hydrous melts in high-pressure and ultra-high pressure rocks: Implications for element transfer in Subduction zones. Lithos, 92: 399-417.

Hess, P.C., 1989. Origins of Igneous Rocks. Harvard University, Cambridge, Massachusetts, Pages: 336.

Hole, M.J., A.D. Saunders, G.F. Marriner and J. Tarney, 1984. Subduction of pelagic sediments: Implications for the origin of Ce-anomalous basalts from the Mariana Islands. J. Geol. Soc., 141: 453-472.

Houghton, B., H. Rymer, J. Stix and S. McNutt, 2000. Encyclopedia of Volcanoes. Elsevier Science & Technology, London, UK.,.

Imami, M.H., 2000. Magmatism in Iran. Publication of Geology and National Mineral Discoveries Organization, Tehran, Iran,.

Irvine, T.N. and W.R.A. Baragar, 1971. A guide to the che-mical classification of the common volcanic rocks. Can. J. Earth Sci., 8: 523-548.

Kamber, B.S., A. Ewart, K.D. Collerson, M.C. Bruce and G.D. McDonald, 2002. Fluid-mobile trace element constraints on the role of slab melting and implications for Archaean crustal growth models. Contrib. Miner. Petrol., 144: 38-56.

Kawamoto, T., 1992. Dusty and honeycomb plagioclase: Indicators of processes in the Uchino stratified magma chamber, Izu Peninsula, Japan. J. Volcanol. Geotherm. Res., 49: 191-208.

Mason, B. and C.B. Moore, 1982. Principles of Geochemistry. 4th Edn., Jonh Wiley and Sons, New York, Pages: 344.

Mohamed, F.H., A.M. Moghazi and M.A. Hassanen, 2000. Geochemistry, petrogenesis and tectonic setting of late Neoproterozoic Dokhan-type volcanic rocks in the Fatira area, Eastern Egypt. Intl. J. Earth Sci., 88: 764-777.

Morata, D. and L. Aguirre, 2003. Extensional lower cretaceous volcanism in the Coastal Range (29 20-30 S), Chile: Geochemistry and petrogenesis. J. South Am. Earth Sci., 16: 459-476.

Mullen, E.D., 1983. MnO-TiO2-P2O5: A minor element Discriminant for basaltic rocks of oceanic environments and its implications for Petrogenesis. Earth Planet. Sci. Lett., 62: 53-62.

Norman, M.D. and W.P. Leeman, 1990. Open-system magmatic evolution of andesites and basalts from the Salmon Creek Volcanics, Southwestern Idaho, USA. Chem. Geol., 81: 167-189.

Pearce, J.A. and I.J. Parkinson, 1993. Trace element models for mantle melting: Application to volcanic arc Petrogenesis. Geol. Soc. London Special Pub., 76: 373-403.

Pearce, J.A. and J.R. Cann, 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. Earth Planet. Sci. Lett., 19: 290-300.

Pearce, J.A. and M.J. Norry, 1979. Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks. Contribution to Mineral. Petrol., 69: 33-47.

Pearce, J.A., 1982. Trace Element Characteristics of Lavas Destructives Plate Boundaries. In: Andesites: Orogenic Andesites and Related Rocks, Thorphe, R.S. (Ed.). John Willey and Sons, UK., pp: 525-548.

Pearce, J.A., 1983. Role of the Sub-continental Lithosphere in Magma Genesis at Active Continental Margins. In: Continental basalts and mantle xenoliths, Hawkesworth, C.J. and M.J. Norry (Eds.). Shiva Publishing, Cheshire, pp: 230-249.

Pecerillo, A. and S.R. Taylor, 1976. Geochemistry of Eocene calc-alcaline volcanic rocks from the Kastamous Area, Northen Turkey. Contrib. Miner. Petrol., 58: 63-81.

Rad, G.F., Droop, G.T.R., S. Amini and M. Moazzen, 2005. Eclogites and Blueschists of the Sistan Suture Zone, Eastern Iran: A comparison of P-T histories from a Subduction Melange. Lithos, 84: 1-24.

Rad, G.R., G.T.R. Droop and R. Burgess, 2009. Early cretaceous exhumation of high-pressure metamorphic rocks of the Sistan Suture Zone, eastern Iran. Geol. J., 44: 104-116.

Rittmann, A., 1973. Stable Mineral Assemblages ofIgneous Rock. Springer, Berlin, Germany,.

Rollinson, H.R., 1993. Using Geochemical Data. Longman Scientific and Technical Insitute, UK., ISBN-10: 0582067014, pp: 352.

Ryerson, F.J. and E.B. Watson, 1987. Rutile saturation in magmas: Implications for TiNbTa depletion in island-arc basalts. Earth Planet. Sci. Lett., 86: 225-239.

Saunders, A.D., J. Tarney and S.D. Weaver, 1980. Transverse geochemical variations across the Antarctic Peninsula: Implications for the genesis of calc-alkaline magmas. Earth Planetary Sci. Lett., 46: 344-360.

Shalley, D., 1993. Igneous and Metamorphic Rocks under the Microscope: Classification, Textures, Microstructures and Mineral Preferred Orientation. Springer, London, UK., ISBN-13: 9780412442001, Pages: 234.

Stewart, M.L. and T.H. Pearce, 2004. Sieve-textured plagioclase in dacitic magma: Interference imaging results. Am. Miner., 89: 348-351.

Sun, S.S. and W.F. McDonough, 1989. Chemical and Isotopic Systematic of Oceanic Basalts: Iimplications for Mantle Composition and Processes. In: Magmatism in Ocean Basins, Saunders, A.D. and M.J. Norry (Eds.). Geological Society, London, pp: 313-345.

Tatsumi, Y. and S. Eggins, 1995. Subduction Zone Magmatism. Wiley, New York, USA., ISBN:9780865423619, Pages: 224.

Tatsumi, Y., D.L. Hamilton and R.W. Nesbitt, 1986. Chemical characteristics of fluid phase released from a Subducted lithosphere and origin of arc magmas: Evidence from high-pressure experiments and natural rocks. J. Volcanol. Geotherm. Res., 29: 293-309.

Tsuchiyama, A., 1985. Dissolution kinetics of plagioclase in the melt of the system diopside-albite-anorthite and origin of dusty plagioclase in andesites. Contrib. Miner. Petrol., 89: 1-16.

Winchester, J.A. and P.A. Floyed, 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chem. Geol., 20: 325-343.

Yoder, H.S. and C.E. Tilley, 1962. Origin of basalt magmas: An experimental study of natural and synthetic rock systems. J. Petrol., 3: 342-532.

Zarrinkoub, M.H., S.S. Mohamadi and F. Yusefi, 2011. Geochemistry and petrogenesis of volcanic and semi-intrusive rocks of Givshad: Southwest of Birja.