Artículo de investigación

Petrology and petrogenesis of the SiahKuh intrusive Massive in the South of KhoshYeilagh

Petrología y petrogénesis del masivo intrusivo de SiahKuh en el sur de KhoshYeilagh
Petrologia e petrogênese do maciço intrusivo de SiahKuh no sul de KhoshYeilagh

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Abstract

SiahKuh is located in the NorthEastern part of Shahrood city and in the Eastern Alborz zone. The study of the area using geochemical models where 60 samples of intrusive rocks were used, allowed to determine that the petrological composition of the region consists of Gabbro, Monzodiorite, Syenite, Monzonite and Diorite. Plagioclase, Pyroxene and Olivine constitute the main minerals of Gabbro`s and Diorite`s. Granular, Intergranular and Optic texture are also observed. In the Syenite and Monzonite, Plagioclase, alkali feldspar and sometimes quartz, granular and variolite texture can be seen. Based on geochemical studies, the magma produced from the rocks to the intermediate calk alkaline with high potassium and the negative anomalies of Nb, Rb, P and the enrichment of the rocks of the region from rare earth elements (LRRE) and the high ratio of LREE/HREE represents spread of the crust and an indication of the presence of the Garnet phase in the mantle source. The initial basalt magma was created from a mantle with a composition of Lerzolite-Garnet with a melting point of 12-15%. Structure evidence suggests the formation of these rocks in the intercontinental rift. The formation of these rocks can be attributed to the effects of intercontinental tensile phases associated with deep fault during alpine orogenic phases in the time eocene.

Resumen

SiahKuh se encuentra en la parte noreste de la ciudad de Shahrood y en la zona oriental de Alborz. El estudio del área utilizando modelos geoquímicos donde se utilizaron 60 muestras de rocas intrusivas, permitió determinar que la composición petrológica de la región consiste en Gabbro, Monzodiorita, Sienita, Monzonita y Diorita. Plagioclasa. Piroxeno y olivino constituyen los principales minerales de Gabbro y Diorita. También se observan texturas granulares, intergranulares y ópticas. En la sienita y monzonita, se puede observar plagioclasa, feldespato alcalino y algunas veces cuarzo, granular y variolita. Con base en estudios geoquímicos, el magma produjo desde las rocas hasta la calca alcalina intermedia con potasio alto y las anomalías negativas de Nb, Rb, P y el enriquecimiento de las rocas de la región a partir de elementos de tierras raras (LRRE) y la alta proporción de LREE / HREE representa la propagación de la corteza y una indicación de la presencia de la fase Granate en la fuente del manto. El magma de basalto inicial se creó a partir de un manto con una composición de Lerzolite-Granate con un punto de fusión del 12-15%. La evidencia estructural sugiere la formación de estas rocas en la grieta intercontinental. La formación de estas rocas se puede atribuir a los efectos de las fases de

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Keywords: Gobbro, diorite, environment tensile, SiahKuh, Iran.

tracción intercontinentales asociadas con fallas profundas durante las fases orogénicas alpinas en el tiempo del eoceno.

Palabras claves: Gobbro, diorita, medio ambiente extensible, SiahKuh, Irán.

Resumo

SiahKuh está localizado na parte nordeste da cidade de Shahrood e na zona leste de Alborz. A área de estudo utilizando modelos geoquímico onde foram utilizadas 60 amostras rochas intrusivas, revelou que a região composição petrological consiste gabro, Monzodiorita, sienite, diorite .. Monzonite e plagioclase. Piroxena e olivina são os principais minerais de Gabro e Diorito. Texturas granulares, intergranulares e ópticas também são observadas. No sienito e monzonito, plagioclásio, feldspato alcalino e, às vezes, quartzo, granular e variolite podem ser observados. Com base em geoquímico, magma produzido a partir de rochas para alcalina calca alta potássio intermediário e anomalias negativas de Nb, Rb, P e enriquecimento das rochas na região a partir de elementos de terras raras (LRRE) e a alta proporção de LREE / HREE representa a propagação da crosta e uma indicação da presença da fase de granada na fonte do manto. Magma de basalto inicial foi criado a partir de um manto com uma composição de Lerzolite-Garnet com um ponto de fusão de 12-15%. Evidências estruturais sugerem a formação dessas rochas na fenda intercontinental. A formação dessas rochas pode ser atribuída aos efeitos das fases de tração intercontinental associadas a falhas profundas durante as fases orogênicas alpinas no período do Eoceno.

Palavras-chave: Gobbro, diorito, ambiente extensível, SiahKuh, Irã.

Introduction

The Alborz Mountains are part of the Alp-Himalayan orogeny belt with a depth of 35 to 40 K.m.(Guest et al., 2007), from the North to the fall of the Caspian block (Zonenshain & Lepichon, 1986) and from the south to the Tabriz-Bezman magma arc and the block of Iran (Guest et al., 2007) is limited. This belt extends from Turkey to Thailand and from the Viewpoint of its tectonic section, the middle part of the Alborz Mountains can be divided into three parts: the west Alborz, the central Alborz and the Eastern Alborz. Along the Alp- Himalaya belt, west Alborz reaches the western part of the MolasOligicene basin to the Quternary in the Coraa basin (Zanchi et al., 2006) and also, reaches the Molas Trance Caucasus basin in the NorthEast of Turkey and the Eastern part of the Molas basin of the North Caucasus (Ershov et al., 2003). After the final Cretaceous compression phase, an important tensile phase throughout Iran (except for Zagros and Kopehdagh) was determined, resulting in intense volcanism and Eocene plutonist in most parts of the Alborz-Azerbaijan. In this area, due to the adaption and correlation of different rock units and geochemical characteristics, the geometry of the magma and the tectonic position of the studied rocks in the studied area have been identified by geochemical modeling, the type of processes involve in the development of the lithological variety of the region.

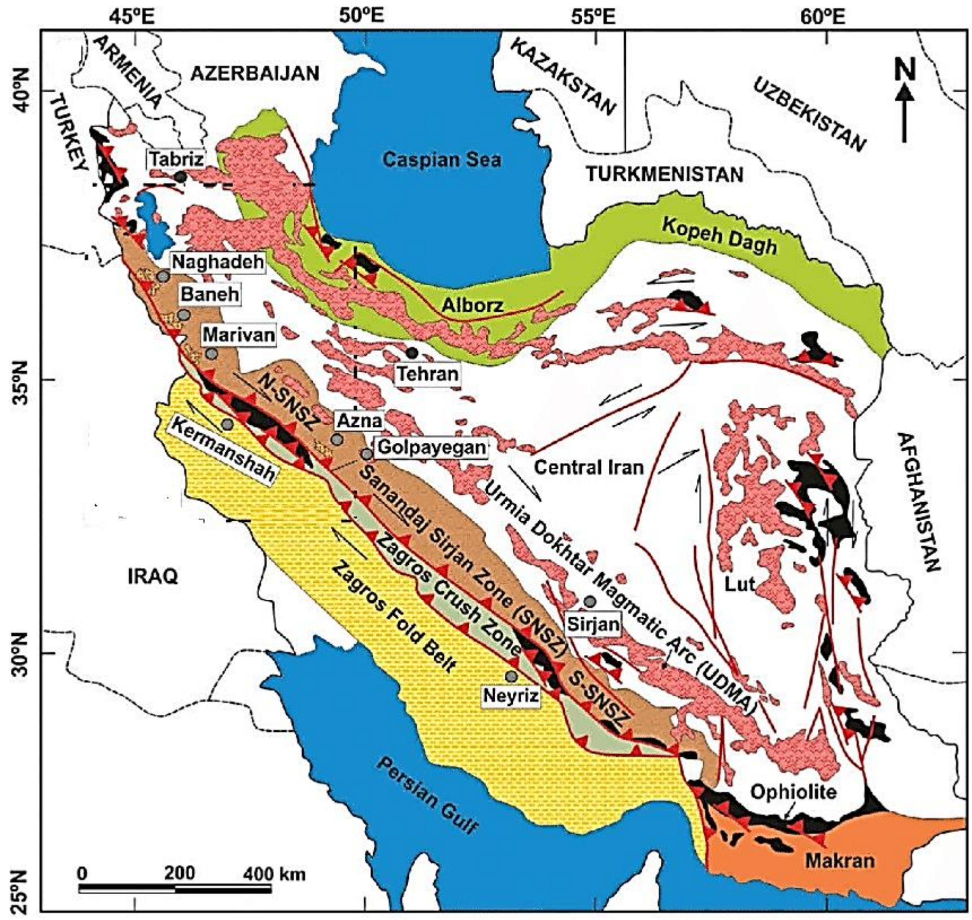

Figure 1. Location of the studied area from (Azizi et al., 2018) modified from the map (StÖcklin, 1968)

Discussions

General geology of the studied area

The study area is located in the Eastern Alborz structural zone, which is located in the province of Semnan in terms of divisions (Figure 1). The area is located between the Eastern Longitude of 55° 9´ and 55° 15´ and the North Latitudes of 36° 33´ and 36° 33´. In theSiahKuh range, the mountain is the oldest outcrop of know Cenozoic rocks, including: Gypsum marl, red gypsum, green marl gypsum, with sandstone layers. The outcrops of rock units in the Eocene period include the formation of dark volcanic rocks with the combination of Andesite, Basalt and with Andesitic tuff and green tuff. The related faults in the SiahKuh area, which are generally southwest- NorthEast, are of a thrust type, can be referred to the Dino fault, Zarrinkamar and Gachboon. the folding of the study area is mainly formed by anticline andsyncline structures, the most important of which is the Dino anticline and syncline the Cheshmehshirin (see figure 2).

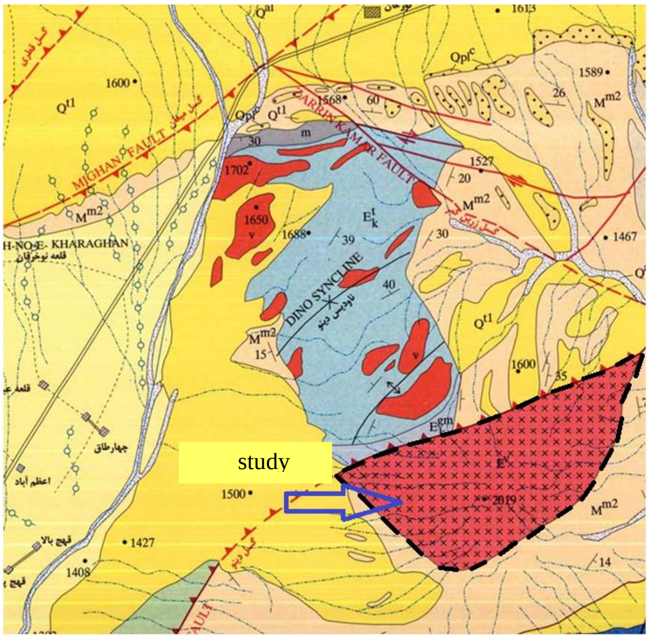

Figure 2. Location of SiahKuh area on part of KhoshYeylagh 1:100000 geological map (Ahangaran&Eshghi, 1383)

Study method

The present study was based on field studies, thin sections studies and chemical analysis of the main and rare elements. Therefore, more than 60 samples of intrusive rocks SiahKuhhave been sampled and thin sections have been prepared. Of the 19 samples, the geochemical analysis of XRF and ICP were the main and rare elements (including rare earth elements) at the S. G. S. laboratory of Canada (Table 1).

Table 1. Coordinates of picked stons from SiahKuh area.

Row	Signs	Kind of stone	Longitude	Latitudes
1	B36	Micro diorite	55° 11' 39.9"	36° 36' 06.6"
2	B41	Diorite	55° 11' 28.4"	36° 35' 49.9"
3	B48	Monzodiorite	55° 12' 03.4"	36° 36' 03.5"
4	B49	Monzodiorite	55° 11' 29.6"	36° 35' 19.8"
5	B50	Monzodiorite	55° 12' 16.5"	36° 35' 48.9"
6	B51	Monzodiorite	55° 12' 38.8"	36° 35' 59.3"
7	B52	Diorite	55° 13' 08.9"	36° 36' 08.1"
8	B55	Monzo diorite	55° 11' 13.3"	36° 35' 36.5"
9	B64	Diorite	55° 12' 38.3"	36° 36' 24.8"
10	B65	Monzodiorite	55° 11' 07.6"	36° 34' 27.6"

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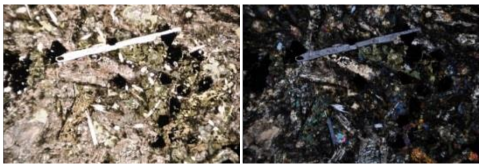
11	M41	Monzosyenite	55° 14' 43.6"	36° 36' 40.1"
12	M42	Quartz monzonite	55° 14' 33.1"	36° 36' 35.6"
13	M44	Quartz monzonite	55° 14' 27.8"	36° 36' 32.5"
14	M46	Monzonite	55° 14' 46.9"	36° 36' 33.0"
15	M50	Micro gabbro (Dolerite)	55° 11' 16.7"	36° 34' 30.1"
16	M52	Gabbro	55° 11' 18.2"	36° 34' 31.4"
17	M54	Monzo gabbro	55° 11' 44.3"	36° 34' 36.3"
18	M57	Gabbro	55° 10' 08.1"	36° 35' 35.3"
19	M58	Monzosyenite	55° 10' 08.3"	36° 35' 35.0"

Petrology study

Based on the study of samples taken, the combined range of rocks of the study area is Gabbro, Monzogabbro, Microgabbro, Diorite, Micro-diorite, Monzodiorite, syenite, Monzosyenite, Monzonite and Quartz-monzonite (Figure 3). Petrography studies on the rocks show that Gabbro and diorite consist of Plagioclase, Pyroxene and Olivine, which is observed in the Granular, intergranular, cavity and optic sections of the texture. Plagioclase, Alkali Feldspar and sometimes quartz, are the main minerals of Syenite and Monzonite and Granular, Rapakivi, Variolite, Perthitetextures are observed. The most important secondary minerals formed in these rocks are Chlorite, clay minerals, Epidote andcarbonate. Apatite is a minor mineral in most of the specimens.



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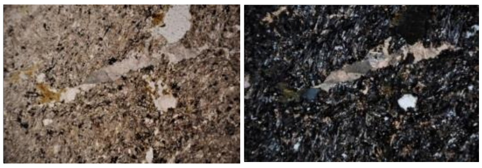

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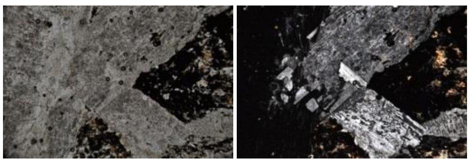

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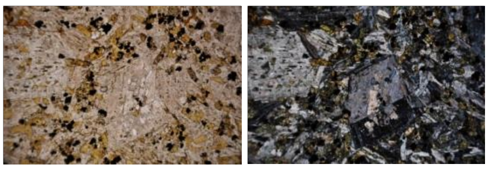

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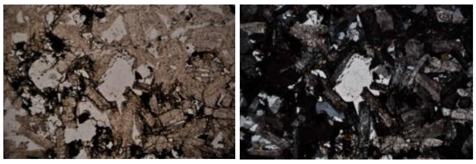

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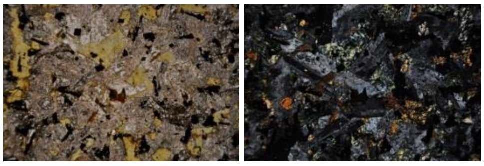

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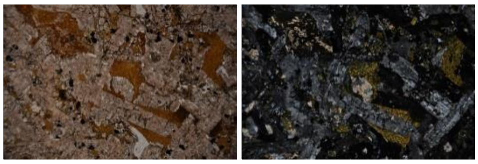

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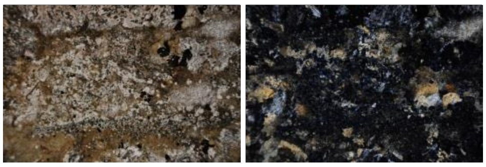

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Figure 3. Range of rocks of the study area: a:Diorite, b:Monzodiorite, c:Microdiorite, d:Syenite, e:Monzosyenite, f:Monzonite, g:Quartz monzonite,h:Gabbro, i:Monzogabbro, j:Microgabbro

Geochemical studies of rock in the region

The study of the main elements of the rocks shows that these rocks are a spectrum of intermediate and alkali rocks. The SiO_2values in these rocks are in the range of 30.42% to 20.77%, and can be divided into groups of Gabbro, Diorite, syenite and monzonite rocks (Figure 4a and 4b). Also, based on the division of the semi-alkali and alkali series (Irvine &Baragar, 1971), the rocks divided are in the range of calc alkaline and alkaline (Figure 4c and 4d). the process of changing the value of the main elements against SiO_2 is presented in Figure 5. As it can be seen, CaO, Na_2O, MgO decrease the SiO_2 in a direction that indicates magma subtraction, but K_2O show an increasing trend. The origin of magma with high potassium is likely to lead to an increase in the K_2O against SiO_2 and also the presence of potassium minerals such as alkali feldspar. Also, can be attributed to the persistence of potassium in the final stage of subtractionmagmatic and it`s concentration in the feldspar phases.

The magnesium number of samples (Gabbro and Diorite) is #Mg between42-76. According to the Kelemen et al., 2004, if the number of magnesium is less than 50, it indicate the evolution of the primary magma and if between 50 and 60, the primary magma is called high magnesium, and if more than 60, that is initial primary magma. Most of the samples are Magnesium in the primary magma range. La vs. Rb diagram (Schiano et al., 2010) and Th/Nb vs. SiO_2 diagram (He, et al., 2010) have been used to find the subtraction crystallization process and the amount of crust spread. The process of samples shows the role of crystallizationsubtraction and the effect of spreadcrust in the evolution of stones in the region (figure 5d). According to Hart et al. (1989), the La/ Nb ratio of more than 1.5 and the La/ Ta ratio of more than 22 indicate magma spread with crust compounds. In the region samples, the ratio of La/Nb is less than 1, and the La/Ta ratio is less than 22, indicating a spreadlow magmatic with crust of rocks.

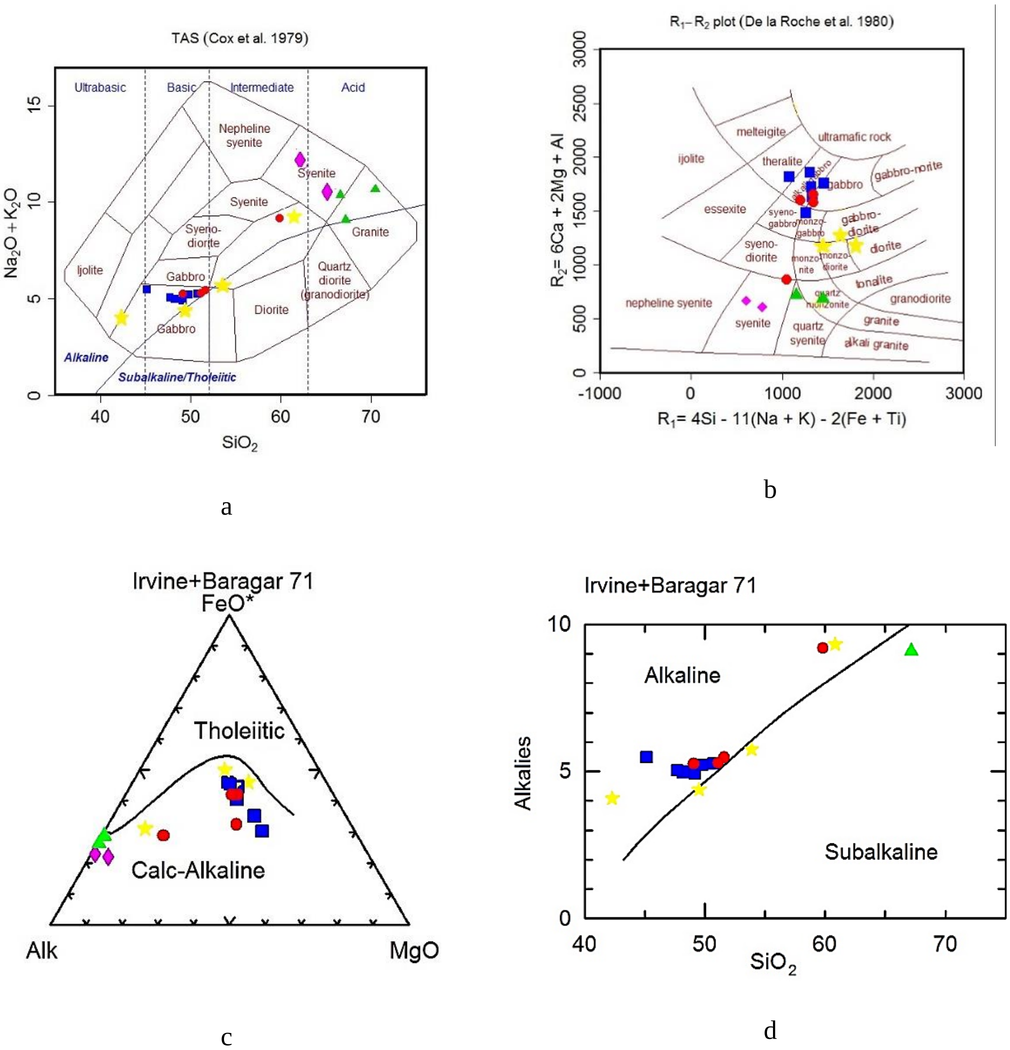
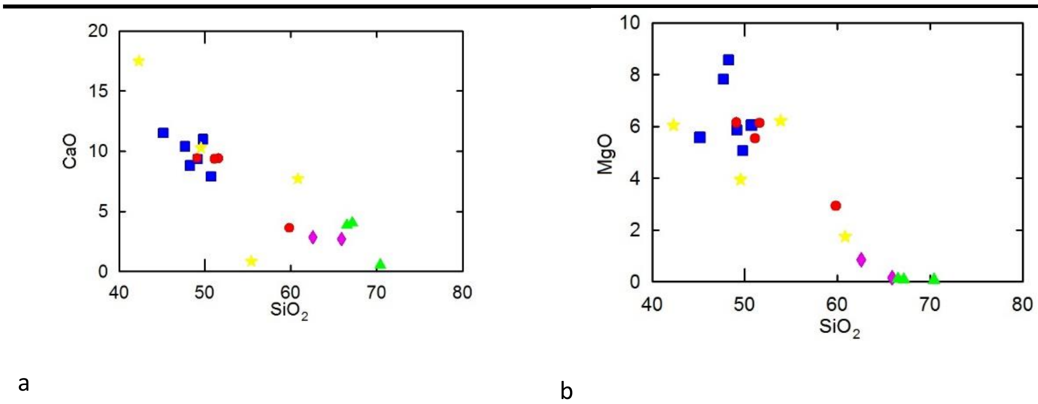


Figure 4. a: Shows Na2O + K2O versus SiO2 (Cox et al., 1979). b:chart De la Roch et al., (1980). c-d: diagrams of magmatic series of Irvine and Barager, (1971).



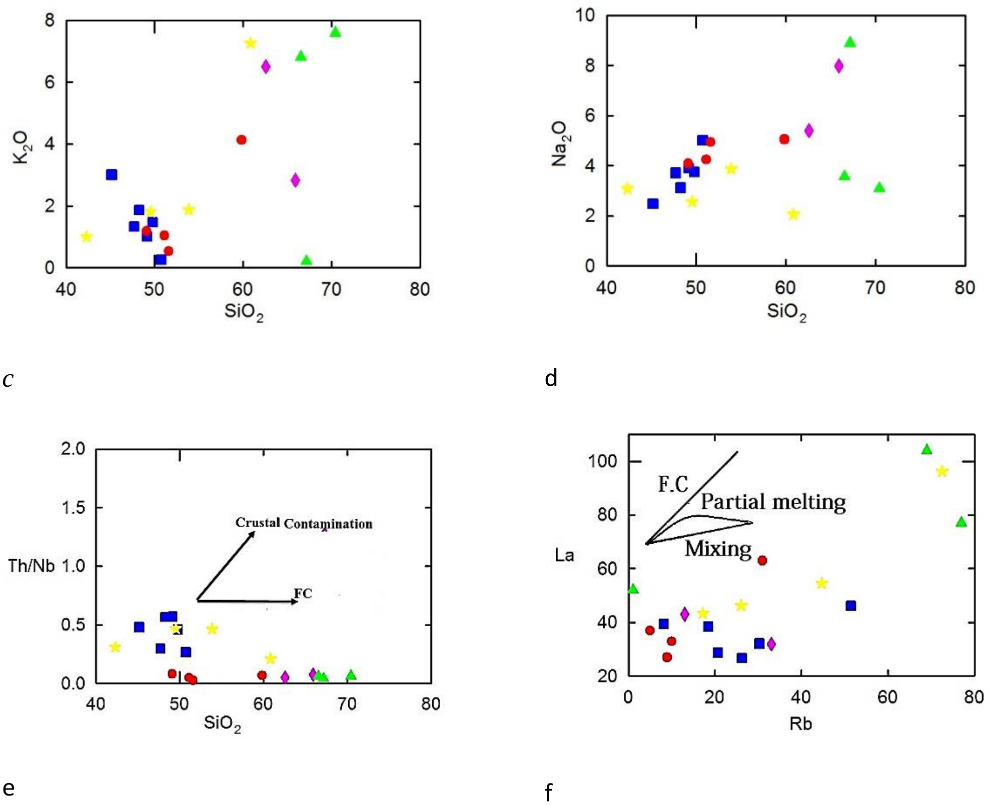
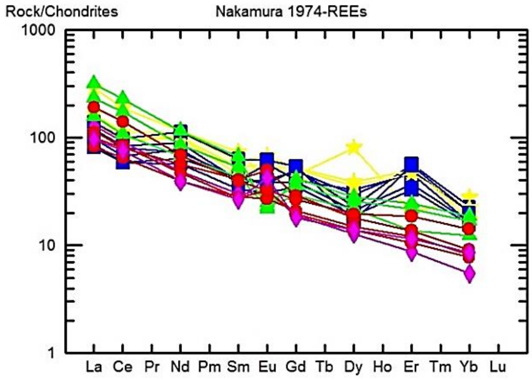


Figure 5. Chart of changes of main elements to SiO2. e: Th/Nb versus SiO2 diagram (He et al. 2010), f: La/ versus Rb diagram (Schino et al., 2010).

For a accurate examination of geological processes and features of the location of the origin of the stones in the region, the normalized pattern of the rare elements and rare earth elements of these rocks so plotted against the values of the Chondrite, the initial mantle and the basalts of the depleted ocean stack (figure 6). In normalized charts, there is no specific incidence of normali in the Eu, which can be attributed to the non-subtraction of Plagioclase and Clinopyroxene (Zeng et al., 2010) during the evolution of the magma forming the rocks of the region. The presence of negative non- normali in Rb, Nb and P also indicated the role of continental crustal magmaspread in the development of rocks in the region.

Highly positive Pb and Ba non- normali of the continental crust have been considered to be ineffective, and the positive anomalies of Sr indicate the presence of the plagioclase in the rock. Enrichment of more than 10 particle size rare earth elements compared to heavy rare earth elements in most samples indicated that garnet was not trend to enter the melt and stay in the mantle of origin. The parallelism of the distribution pattern of rare earth elements, their almost constant variation and the degree of slope of the distribution pattern of rare earth elements is due to the effect of crystallization in the development of various types of rocks to the middle. The relatively high HREE/LREE gradient in the graphs is indicative of the presence of a garnet phase in the mantle source, which suggests a deep source of garnet -Lerzolite with Phologopite /Pagasite (mantle hornblende) with a pressure of 5.2-2 Gpa for alkaline basalt with these conditions (Thirlwall et al., 1990, Tappa 2004; Stivenson 2003; Glasser et al., 1999).



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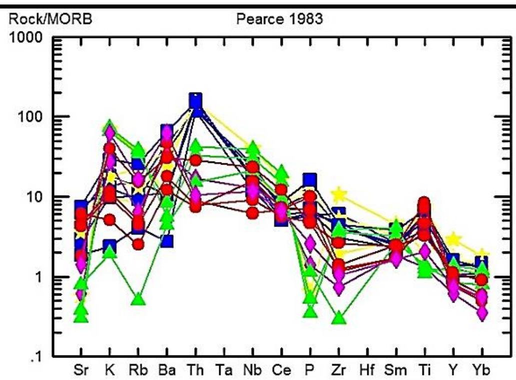

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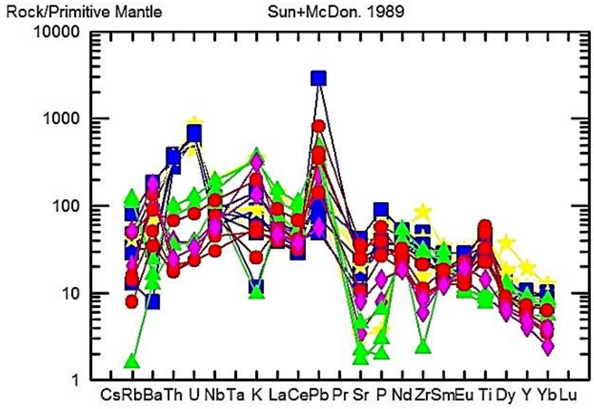

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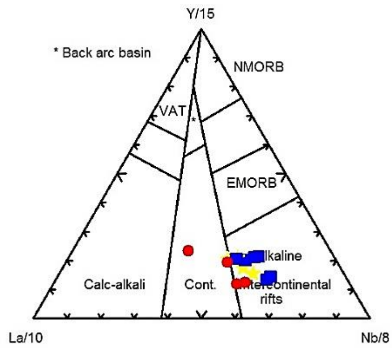
Figure 6. Rare elements and rare earth elements from the rocks of the region that have been normalized to the values of Chondrite and the initial mantle and the middle ocean right basalt depleted (Sun & McDonough, 1989).

Various graphs have been used to determine the tectonic position of the rock forming magma of the area. In the diagram of Y/15-La/10-Nb/8(CabanisLecolle, 1989), samples of Gabbro and Diorite in the range of intracontinental alkaline rift and in diagram versus chromium (Pearce, 1982), samples were placed within the intercontinental basalt. In the Biermanns, 1996, which is special for gabbro, samples of gabbro are located within the boundaries of the rift within the continent (Figure 7).



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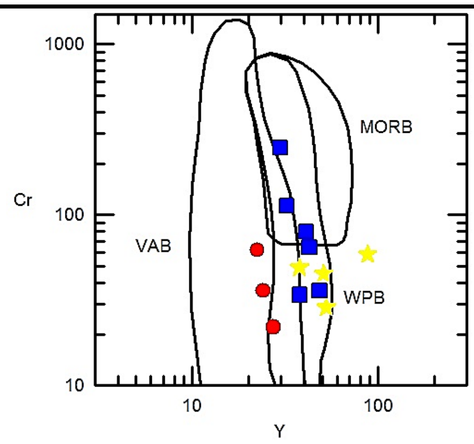

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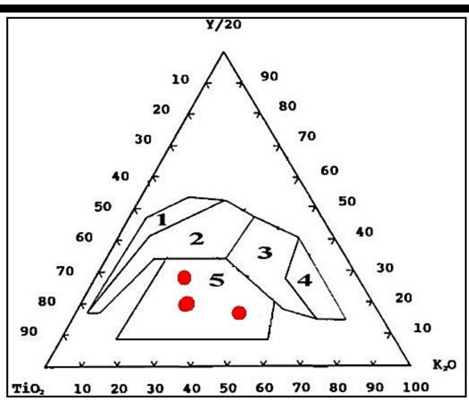

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Figure 7. a: diagram (CabnisLecolle, 1989); b: Chart (Pearce, 1982), c: chart Biermanns, 1996, initial. 1. Gabbro of the arc islands, 2. Developed oceanic island basalts, 3.arc continental gabbro, 4. Gabbro caused by the continental- continental collision, 5. The rift gabbro within the continent.

We used the melting part of the melting curve for Spinel Lerzolite (Sp11+Cpx15+Opx25+Ol53) and garnet peridotite (gt10+cpx10+ opx20+Ol60) as shown in figure 8. In both curves, Gabbro samples of the region are in the range of Garnet -Lerzolite. In general, Yb is consistent with Garnet, while La and Sm are incompatible. This causes Sm/ Yb and La/ Yb heavily concentrated during low-melting periods in the source of Garnet peridotite. In constract, during the melting of the part in the Spinel stability range, the La/Yb ratio is only slightly subtraction and the Sm/Yb ratio remains almost unchanged (Xu et al., Yaxley, 2000; White &Mckenzi, 1995). In the La/Yb diagram against Dy/Yb, Gabbro samples of the region range from 12 to 15 percent of the GarnetPeridotite (Figure, 8b).

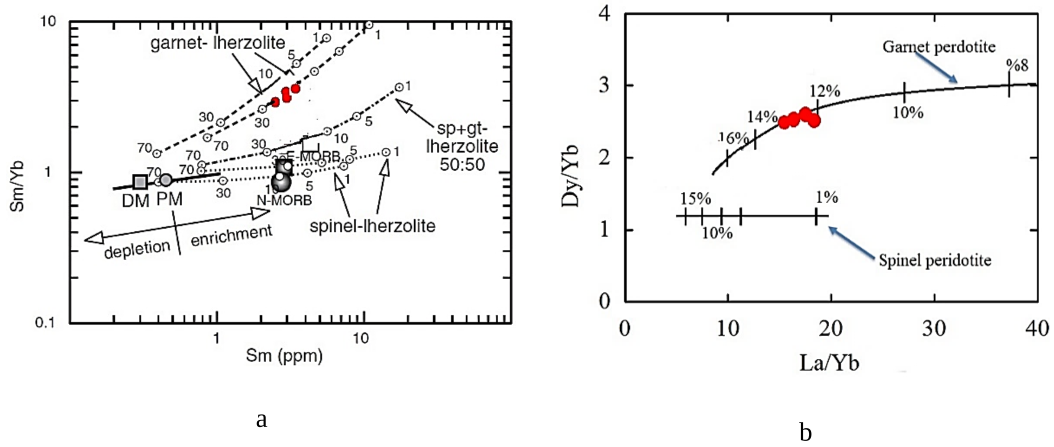

Figure 8. a: Sm diagram against Sm/Yb (Green, 2006); b: Dy/ Yb diagram against La/ Yb from Thirlwall et al., (1994); and Bogaard et al., (2003) for determining the melting range partly.

Presentation of geodynamic model for the formation of igneous rocks in the studied area

Stratigraphic and structure studies conducted by Allen et al., (2003) show that AMC volcanoclastic deposits are formed during a tensile phase in the initial Eocene, and Asiabanha and Foden (2012) suggest that stretch occurred in a back- arc environment. Due to the uplift of the basin during the pressure regime during the final Eocene, the next volcanic phase occurred as a sub-aerial. Considering the above mentioned and researches, the following model is proposed for the Eocene- Oligocene magmatism activity in Alborz and the study area, which is similar to the Humphreys et al., (2003) model, which consists of four steps:

1. In the first stage, the slope of the oceanic crust leads to the formation of an arc or volcanic rock in the north of the Arabian- Eurasian structural zone.

2. In the second stage, after the aptian - albianorogeny phase, subduction continued with a slope and caused magmatic activity in northern central Iran and Alborz. at the end of the Cretaceous, a series of tectonic contractions in Iran is carried out to the north of this structural zone, also in this stage, the upper mantle in the mountains of Alborz and northern Iran.

3. At this stage, the Eocene is roll back into the oceanic crust. The reasons for rollback are numerous and depend on the speed of subduction, the age of the sheet, the density difference between the sheet and the mantle,… (Heuret and Lallemand, 2005). This action causes stretching and thinning in the skin and asthenosphere. The melting of hydrated peridotite in the mantle is due to the reduction of pressure and heat. The magma resulting from this melting of the HFSE elements is depleted but during the subduction it is enriched by the depletion function of some elements. At this stage, volcanic activity and shallow see sediments are formed in tensile environments. The resulting magmas climbed along the deep faults in the tensile zone, during the ascent, undergone various petrological processes such as crystallization of the crust with digestion and crusting. Alkaline magmas have been able to erupt lava in a lake environment in the formation of red marl deposit, or intrusive into the lower red formations in the form of deep and semi- deep deposits.

At this stage, with the starting Oligocene, the rise asthenosphere occur due to thinning in the lithosphere. The melting of the part in the asthenosphere leads to the formation of basaltic magma in the tensile basins at this time. These basaltic magmas are less contaminates due to thinning in the shell and more characteristic of the initial magmas (Plank and Langmuir, 1988; Glazner and Usseler, 1989).

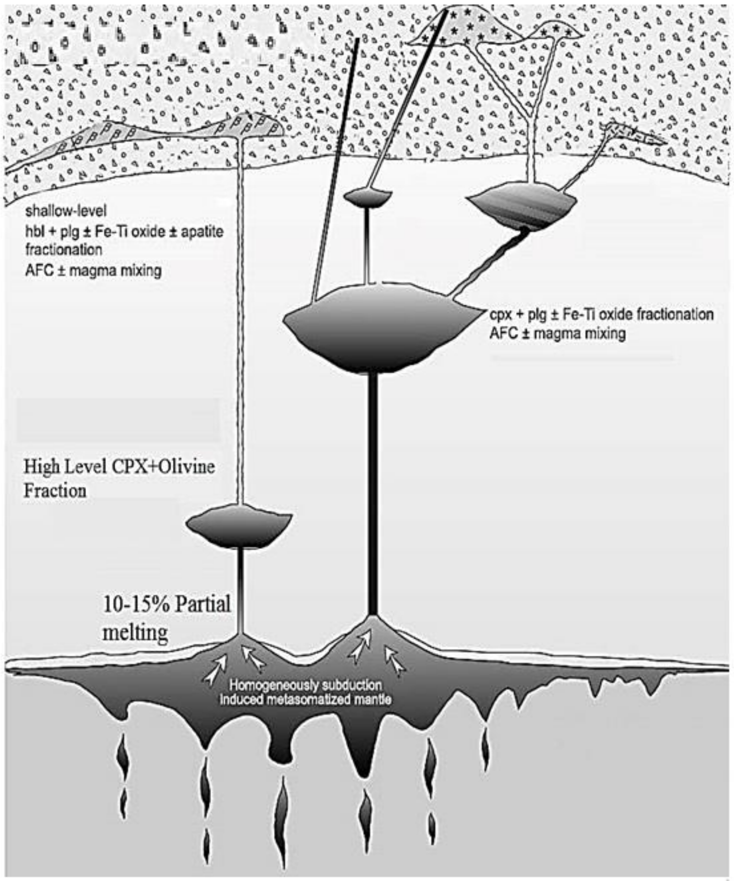

Figure 9. Schematic view from the time of the formation of the alkaline magmas of the Eocene volcanic rocks to the penetration of the Black Mountains intrusive from the design (Temizal and Arslan, 2008).

Conclusion

According to studies, rock units of the region are divided into basic intrusive rocks to intermediate and Pyroclastics. Intrusive rocks from the basic to middle including: gabbro, diorite, monzonite andSyenite and have the nature of Alkaline. The study of the normalized graphs shows that the rocks of the region originate from a partly enriched asthenosphere mantle similar to the source of the OIB with a melting point of 12 to 15 with the composition of the Lerzolite-Garnet. Due to tectonic diagrams and geospatial studies Siah Kuh rock has been formed in an intercontinental tensile setting.

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