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STUDYING THE GENESIS OF IGNEOUS ROCKS IN ZARIN-KAMAR REGION (SHAHROOD, NORTHEASTERN IRAN) BY RARE EARTH ELEMENTS

Ebrahim Nazemi[1]
Mohammad-Ali Arian[2]
Abdolreza Jafarian[3]
Mohsen Pourkermani[4]
Abdollah Yazdi[5]

Abstract: Zarin-Kamar region is located north east of Shahrood ($36^o37'$-$36^o42'$N, $55^007'$-$55^012'$E). Plutonic rocks in this area belongs to syenite group and their texture is intergranular hypidiomorphic. Volcanic rocks in the area have porphyritic, amygdale intersertal texture. which quartz is also seen among their cavities and porosities. Total concentration of REEs (ΣREE) in the study igneous rocks varies between 450 and 683 ppm. Diagram of Eu/Eu^* versus Sr and Eu/Eu^* versus Ba show negative anomalies of Eu. This phenomenon as well as Ba and Sr trends show that plagioclase removal has happened during the magma evolution. These rocks have rock has originated from an enriched mantle source. The rate of Dy/Yb in the igneous rocks of the region varies between 1.32 and 2.62. it shows that it stemmed from a garnet lherzolitic source. The rate of (Tb /Yb) N was between 0.97 to 2.25 showing a garnet source. Also other related figures showed that the samples belonged to OIB (Oceanic Island Basalt). The rate of La/Ta was between 6.6 to 14.01. It also showed that they had a source from asthenosphere. The rate of La/Nb was 0.5 to 0.91. It also shows a less crustal contamination among these samples.

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[1]Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran.
[2]Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran.
Corresponding author: maa1361@yahoo.com
[3]Department of Geology, Shahrood Branch, Islamic Azad University, Shahrood, Iran.
[4]Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran
[5]Department of Geology, Kahnooj Branch, Islamic Azad University, Kahnooj, Iran

Keywords: plutonic, intergranular, hypidiomorphic, volcanic, porphyritic, asthenosphere, crustal contamination.

Introduction

The study rocks involve two types of igneous rocks, intrusive and volcanic. The intrusive ones are alkali aegirine syenite and alkali feldspar aegirine quartz syenite. The volcanic ones are aegirine trachyte types. The minerals detected in XRD were as same as those minerals highlighted in thin section. There is no plagioclase in thin sections of Zarin-Kamar igneous rocks which confirmed the negative anomaly of Eu (Nazemi et al, 2017; Yazdi et al., 2017; Yazdi et al., 2019; Ghadimi and Khavari., 2019). Dominate process in the evaluation of the study rocks was fractional crystallization (Nazemi, 2017). Ti, P, and Sr are deplated while Rb, Th, and U are enriched in the study samples. The ratio of La/Ta was 7.13 to 14.01. Crustal contamination played no significant role on evolving the rocks in the region. However, this little contamination showed that speed of magma rise from magma could be significantly high.

Alkali feldspar quartz aegirine syenite (A3)

Alkali feldspar crystals are seen in different shape in this sample. Some of them has been getting dusty color. The feldspars has cut each other and their abundance is 80 to 95 percent. Quartz among the minerals Located has 5 to 10 percent of the total abundance. Pyroxene crystals are coarse and subhedral with dark green color and they also have zoning. Pyroxene is considered as one of the keys of fractional crystallization phase in alkaline magmatic systems. It is also considered as a potential for enriching the rare earth elements during the crystallization (Charlie Beard et al., 2017; Mobashergarmi et al., 2018). Amphibole crystals have also parallel cleavage and they are elongated and amorphous. Their color is green to brown (Figure 1). In the XRD analysis report Major phases are microcline and acmite (figure 2).

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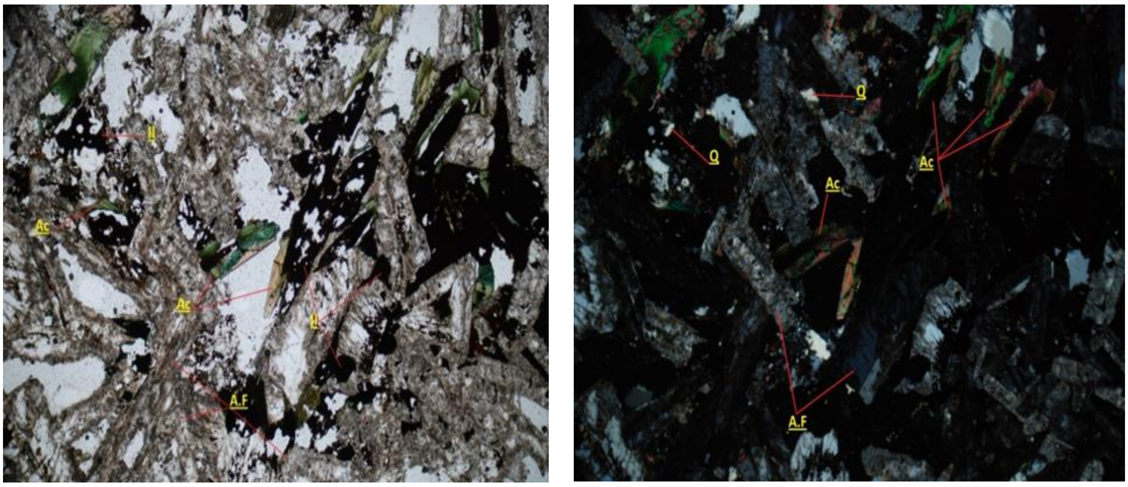

(PPL) (XPL)

Figure. 1. microscopic image of alkali feldspar syenite in Zarin-Kamar; feldspar crystals are dusty and gray that cut each other with different shapes. A pyroxene mineral can be seen at the center of the image with hour glass zoning.

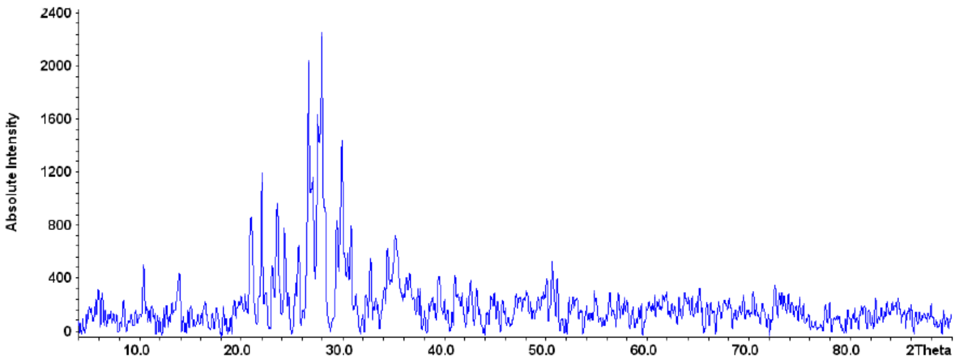

Figure. 2. XRD analysis of A3; alkali feldspar aegirine syenite in Zarin-Kamar region. Major phases are microcline and acmite.

Aegirine trachyte

In this sample, alkali feldspar crystals are wide, large and elongated with simple twining are set in the microcrystal and microlitic texture. These phenocrysts are different in size and they show carlsbad twining gathering at one spot. Their abandance is 90 to 95 percent. Quartz crystals are xenomorphic with the abandance of 5 to 10 percent. Inplane polarized light, pyroxene is brownish green to olive green associated with microcrystalline xenomorphic feldspar crystals. The texture is porphyritic to glomeroporphyritic (Figure 3).

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
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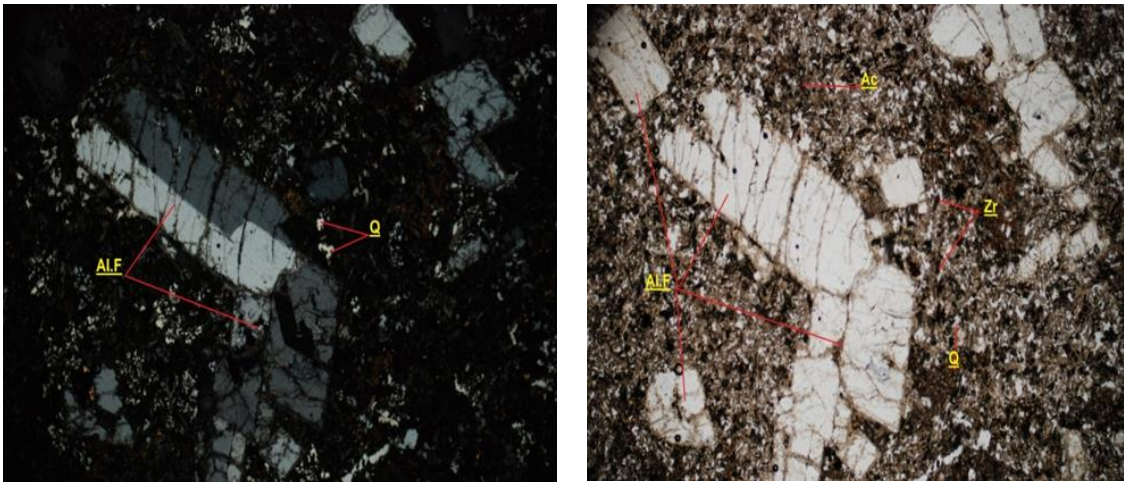


(XPL) (PPL)

Figure. 3. microscopic image of aergine trachyte in Zarin-Kamar region. Elongnated alkali feldespar minerals (sanidine) are seen as porphyritic to gelomoroporphyritic crystals.

Geochemistry

Based on the total alkali values versus silica (Middlemost, 1985) for plutonic samples, the samples are located in syenite and quartz monzonite field. These samples are located in trachyte and rhyolite field for volcanic samples of TAS diagram(Middlemost, 1994) (Figure 4 and 5). Based on A/CNK-A/NK (Shand, 1943) diagram, the study rocks are within per alkaline type (Figure 6). Based on the upward trend in conpatible versus non-conpatible elements, the major process taken place in the rocks is Fractional crystallization (Figures 7, 8, 9 and 10). This phenomenon can be proved based on Rb/V versus Rb, La versus Rb, and Rb versus Rb/La diagrams (Schiano et al, 2010) (Figure 11).

Barium (Ba) has been captivated in potassium compounds and minerals due to its higher coordination number. Barium shows a downward trend versus silica. It also shows an upward trend versus potassium. Existence of potassium alkali feldspar minerals in thin sections confirm this theory significantly (Figure 12-13). Since the magma source of the study samples has high potassium, strontium (Sr) like Barium (Ba) takes part in the feldspar crystals. It shows a downward trend versus silica (Figure 14 and 15).

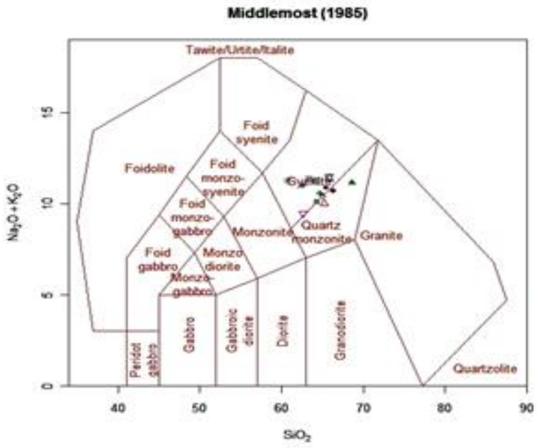


Figure. 4. TAS diagram for the study plutonic rocks (Middlemost, 1985)

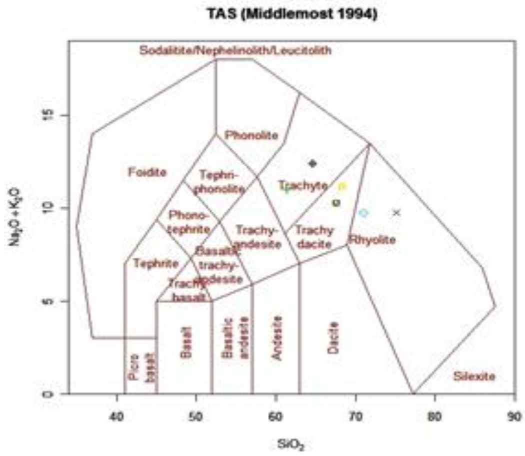


Figure. 5. TAS diagram for the study volcanic rocks (Middlemost, 1994)

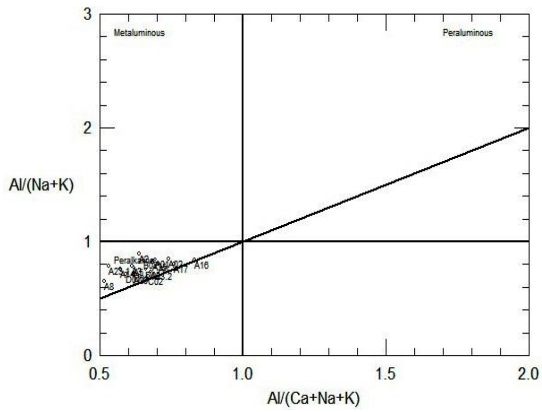
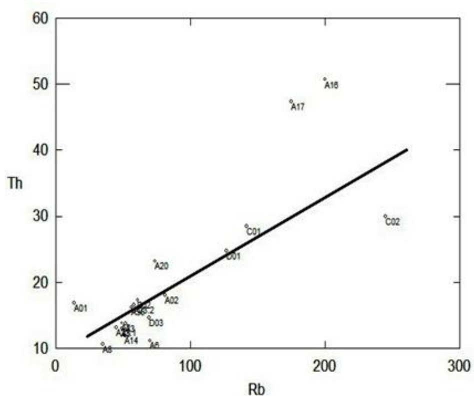


Figure. 6. A/CNK-A/NK diagram (Shand, 1943) for igneous rocks of Zarin-Kamar region.



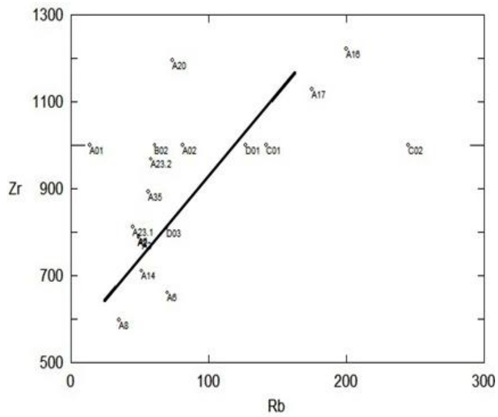


Figure. 7. Incompatible elements diagram (Th Vs Rb) for the study rocks.

Figure. 8. incompatible elements diagram (Zr Vs Rb) for the study rocks.

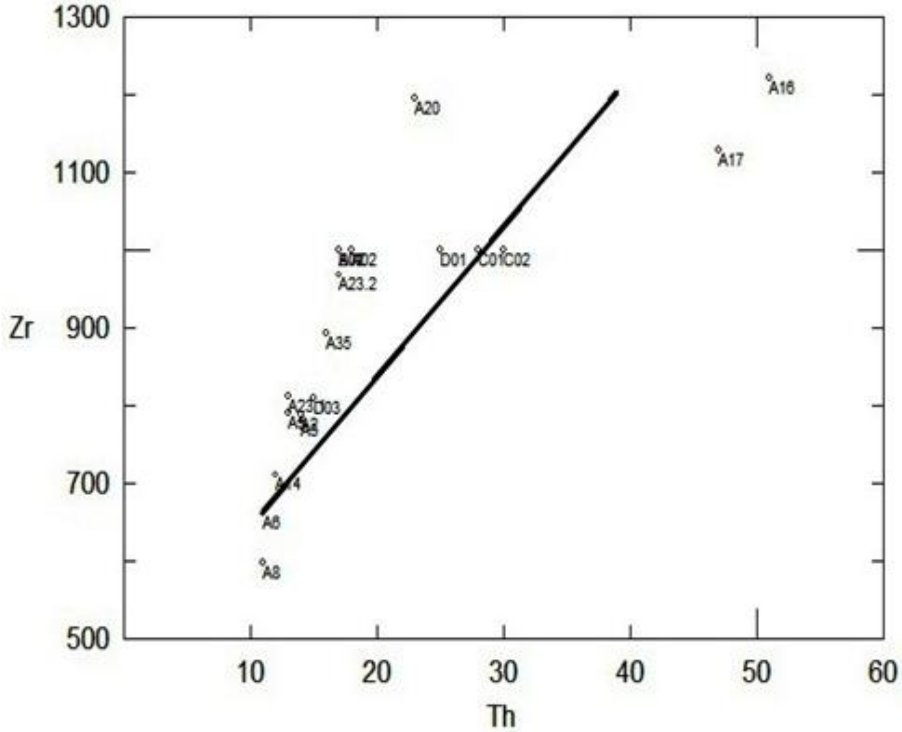


Figure. 9. incompatible elements diagram (Zr Vs Th) for the study rocks.

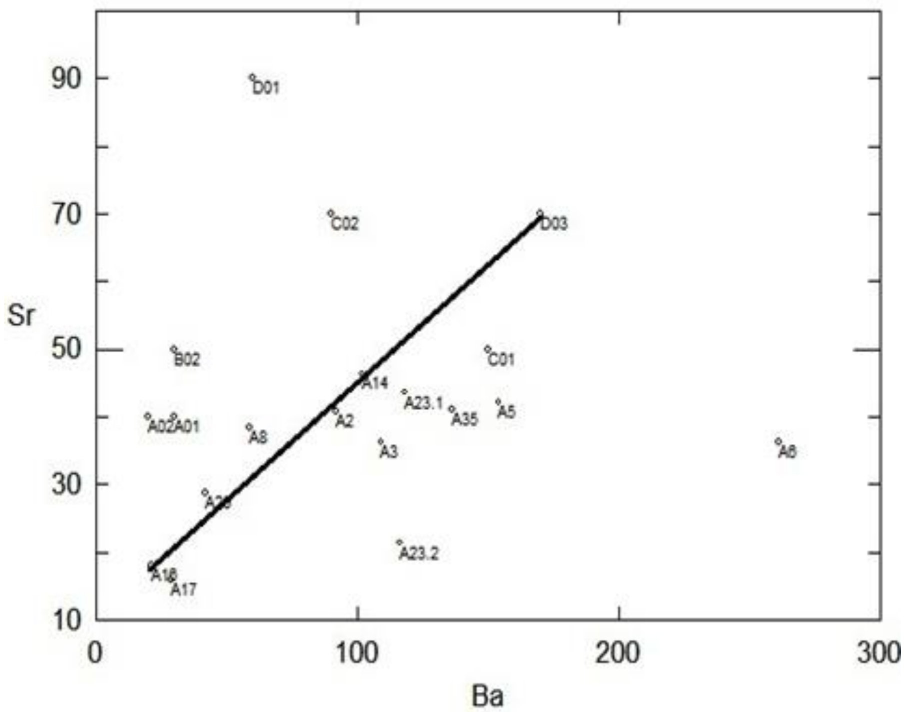


Figure. 10. incompatible elements diagram (Sr Vs Ba) foe the study rocks.

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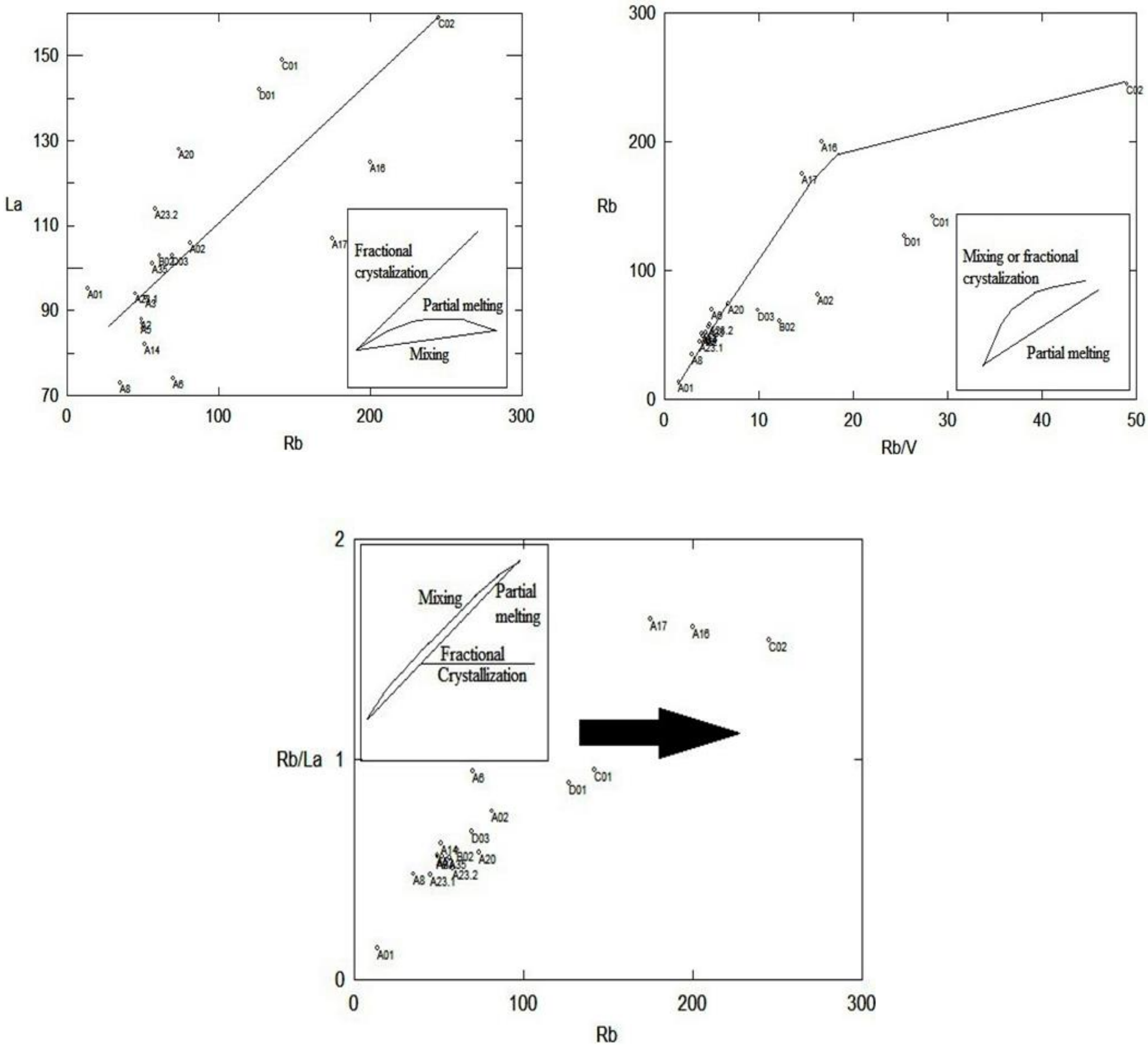

Figure. 11. Petrogenic diagrams (Schiano et al , 2010) of the rocks in Zarin- Kamar.

Comparing to the primary mantle (Figure 16), The samples are depleted in Sr, P, and Ti and enriched in Rb, Th, and U. Negative anomaly of Ti and P can express a continental crust source as well as contamination by lower continental crust (Castillo et al 2006; Khodami and Kamali Shervedani 2018). Appearance of titanium minerals as well as apatite and alkali feldspar and also contamination with crust and existence of shoshonitic magma are responsible for negative anomalies of Ba, Sr, P and Ti, respectively. Normalized REEs to chondrite (Boynton, 1984) shows an enrichment of LREE to HREE. This enrichment is the characteristic of OIB revealing a presence of residual garnet in the source (Figure 17). in the diagrams of Eu/Eu* versus Sr and Eu/Eu* versus Ba. Negative anomalies of Eu associated with Ba and Sr (Figures 21 A - B) show that plagioclase has been removed during magma evolution. A direct relationship is also seen in the diagram of Ba versus Sr as a result of alkali feldspar crystallization (Figure 15). Generally, the diagrams of segregation of alkali feldspar show that plagioclase has been removed during magma evolution and alkali feldspar has been crystallized.

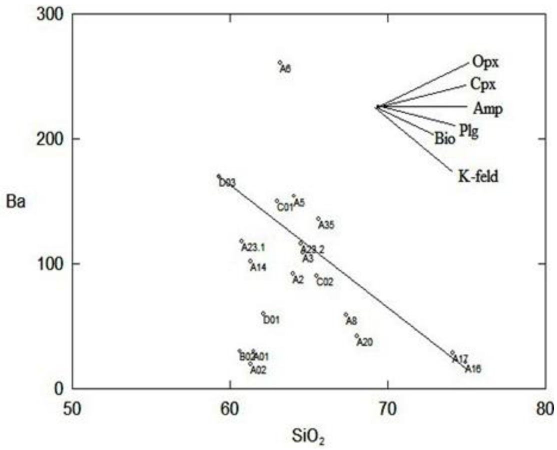

Figure. 12. Diagram of Ba versus SiO_2 for the study rocks.

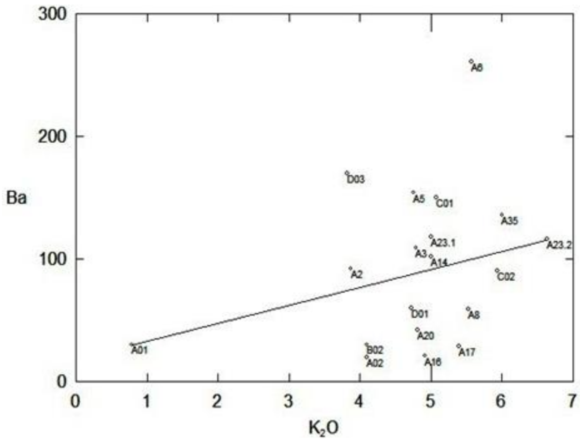

Figure. 13. Diagram of Ba versus K_2O for the study rocks.

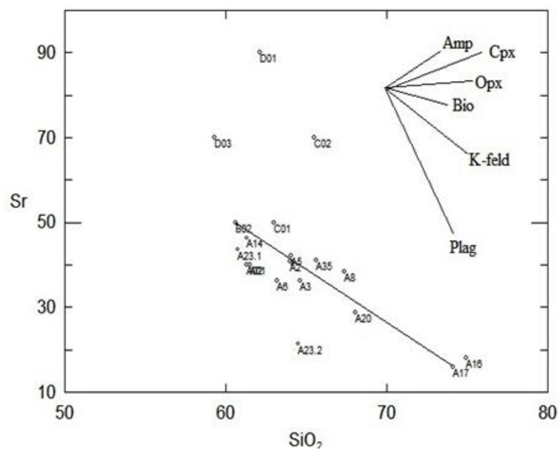

Figure. 14. Diagram of Sr versus SiO_2 For the study rocks.

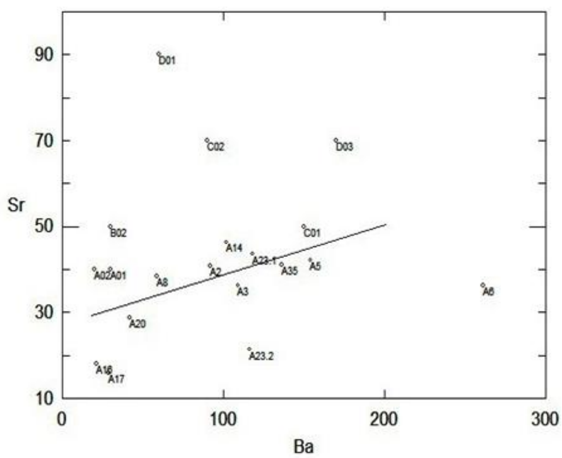

Figure. 15. Diagram of Sr versus Ba For the study rocks.

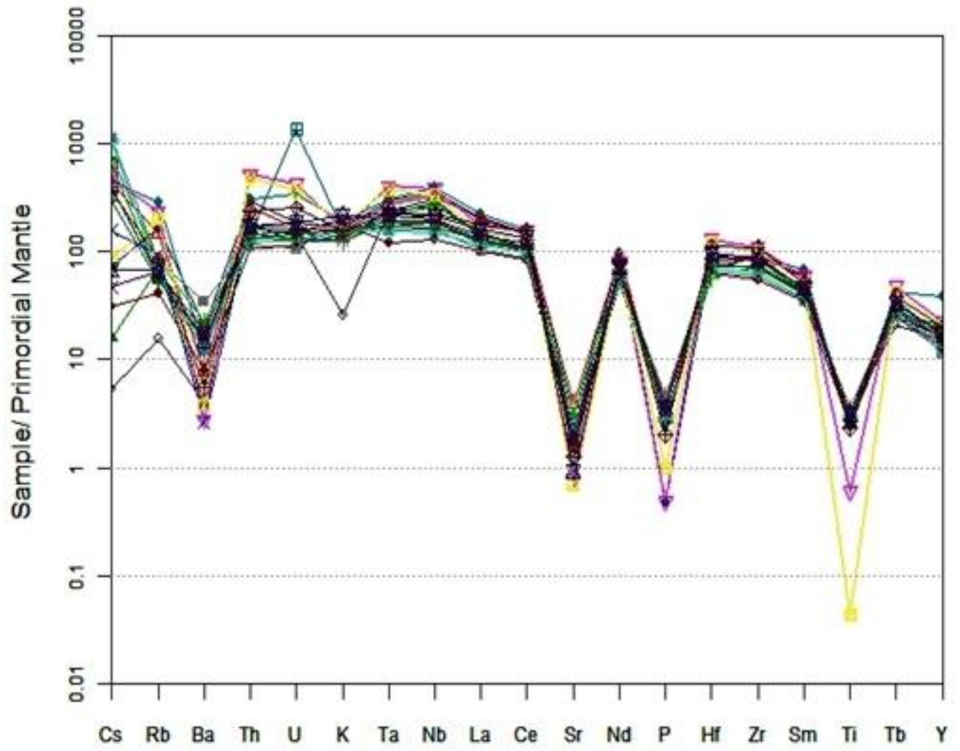

Figure. 16. Primordial mantle (Wood et al, 1979 a), normaliz spider diagrams for the study rocks.

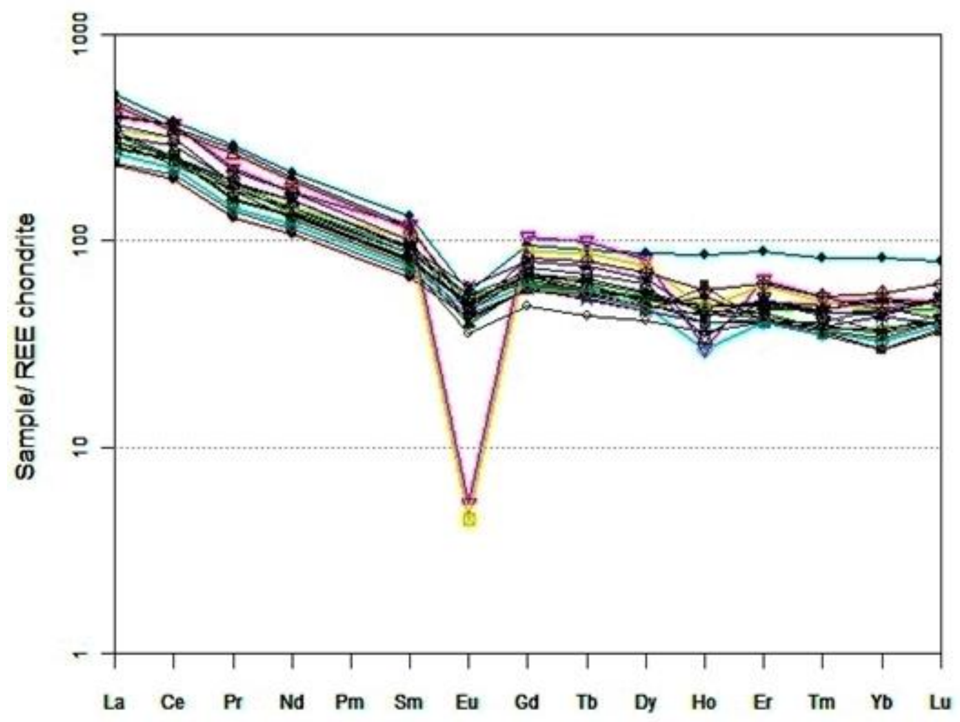

Figure. 17. conderite (Wood et al, 1979a), Normalized spider diagrams for the study rocks.

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
Centro de Ciências Jurídicas - Universidade Federal da Paraíba
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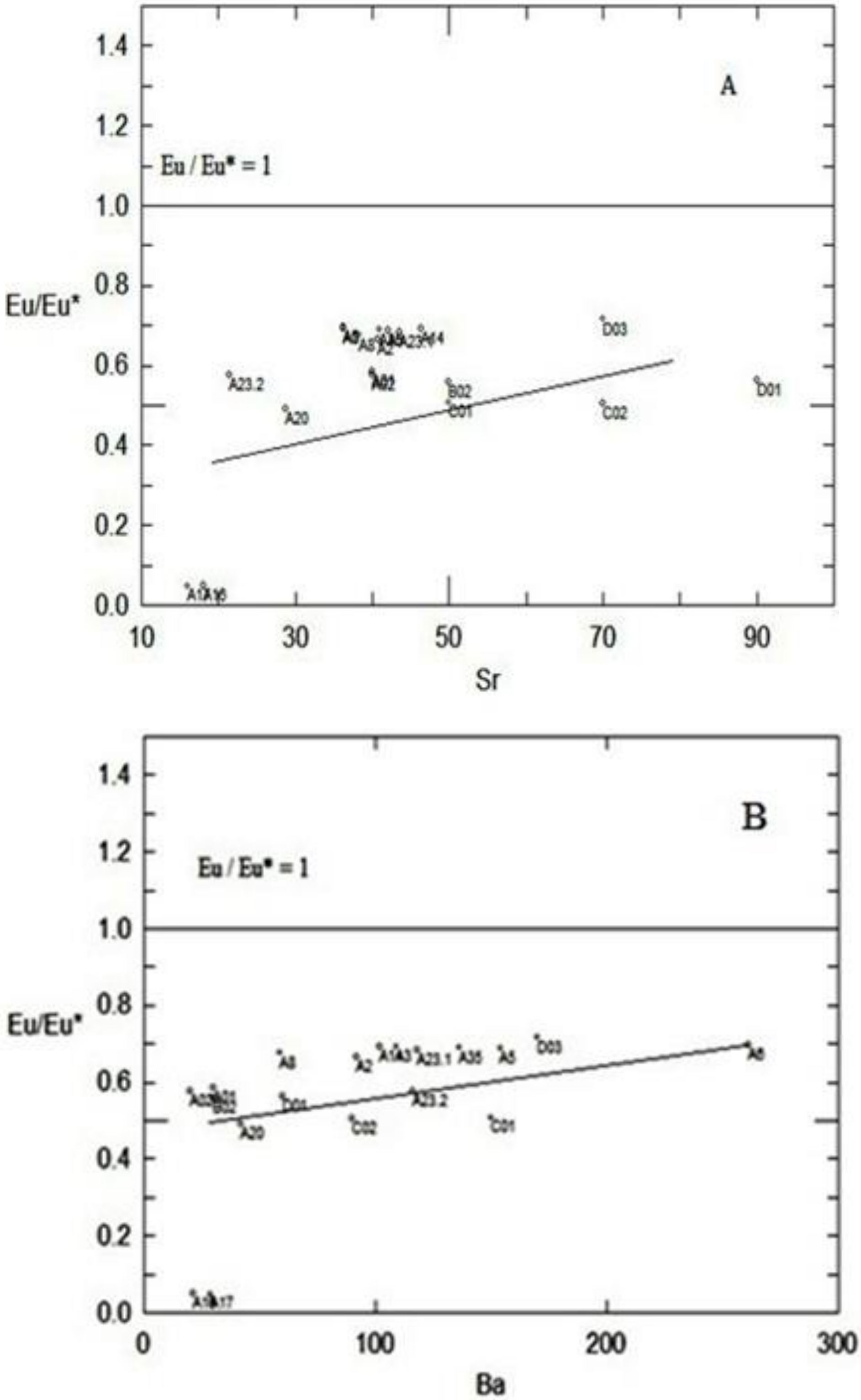

Figure. 18. Diagrams of crystallization of alkali feldspar (Rollinson, 1993) [As is seen from the feldspar subtraction diagrams, plagioclase in the samples has been removed during magma evaluation and alkali feldspar has been crystallized].

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
Centro de Ciências Jurídicas - Universidade Federal da Paraíba
V. 8 - Nº 04 - Ano 2019 – Special Edition
ISSN | 2179-7137 | http://periodicos.ufpb.br/ojs2/index.php/ged/index

Determining the composition of the source magma

Based on the Y-Zr diagram (Abu-Hamatteh, 2005; Novruzov et al., 2019), the samples have been originated form a zirconium enriched mantle source. Based on the diagram of Th/Yb versus Ta/Yb (Pearce, 2008) using relative HFSE elements for defining petrogenetic properties of igneous rocks, fractional crystallization is responsible for generating the igneous rocks of Zarin-Kamar region with OIB source. Based on the diagram of La/Yb versus Nb/La (Bradshaw, and Smith, 1994) which OIB given from Fitton et al.,(1991) and average value of the lower crust (Chen, W. and R.J. Arculus, 1995), the igneous rocks of Zarin-Kamar have been located within the asthenosphere part of the mantle. The samples are subjected to be in OIB based on Zr/Nb versus Zr/Y diagram (Abde – Rahman, and nadear, 2002) as well as TMORB and NMORB diagrams (Menzies, and Kyle, 1990). Based on the Nb/Yb versus Th/Yb diagram (Pearce, and Peate, 1995), Zarin-Kamar samples belong to a region with OIB source and a yellow arrow indicates a crustal contamination.

The samples also belong to OIB based on the diagrams of Yb/Nb versus Ce/Nb and Y/Nb versus Yb/Ta (Eby, 1990) Range of La/Ta ratio is 6.6 to 14.01 ppm indicating an asthenosphere mantle source. Base on the (Thompson, and Morrison , 1988), (Leat et al., 1988) and theories, a ratio of La/Ta has been used to highlight the difference between magmas with asthenosphere source related to rifts and crustal contamination. Also, (Leat et al 1988) pointed out that rocks with the ration of Ta/La less than 22 have been originated from an asthenosphere source. While (Thompson and Morrison, 1988) has raised this theory that rocks with ratio of La/Ta less than 10-12 have been originated from an asthenosphere source and the ratio of La/Ta more than 30 indicates crustal contamination. Enrichment of LREE to HREE which highlights the low value of (Tb/Yb)N presents a garnet source for the study area (the rate of (Tb/Yb)N is between 0.97 to 2.25). The ratio of Dy/Yb in the samples is between 1.32 to 2.69 indicating that the samples have been originated from a lherzolitic garnet source (Sayıt and Goncuoglu, 2009). Based on the (Kearey and Vine, (1990).

V. 8 - Nº 04 - Ano 2019 – Special Edition
ISSN | 2179-7137 | http://periodicos.ufpb.br/ojs2/index.php/ged/index

upper mantle has a peridotite composition with a high amount of olivine and a limited amount of garnet (Less than 15 percent). Residual garnet left in the magma shows that the magma production occurred in the depth of at least 80 km (Wilson, 1989). The samples collected from the study area have located in OIB part. It is important to notice that the two samples of A16 and A17 have been plotted farther than the other samples indicating a higher crustal contamination in these two samples. The yellow arrow shows a contamination phase.

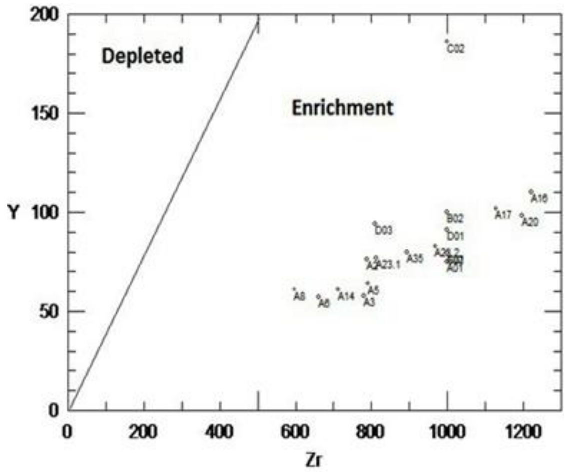

Figure. 19. The diagram of Y versus Zr (Abu-Hamatteh, 2005) for the study rocks.

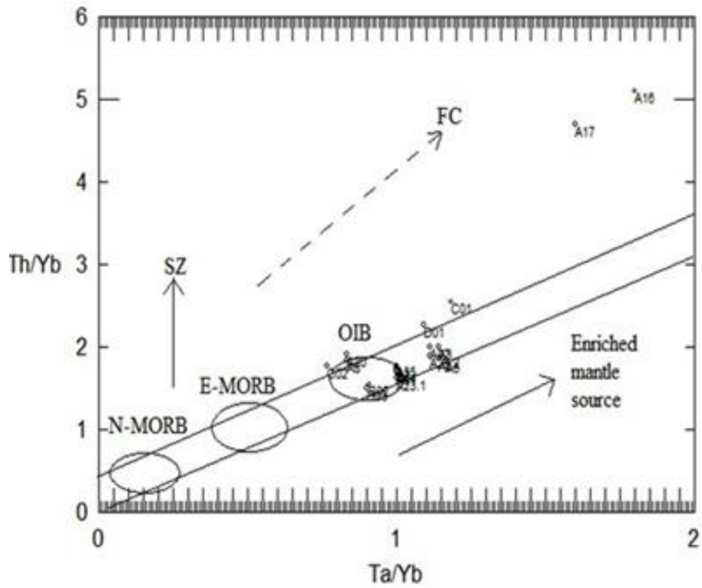

Figure. 20. The diagram of Th/Yb Versus Ta/Yb for the study rocks.

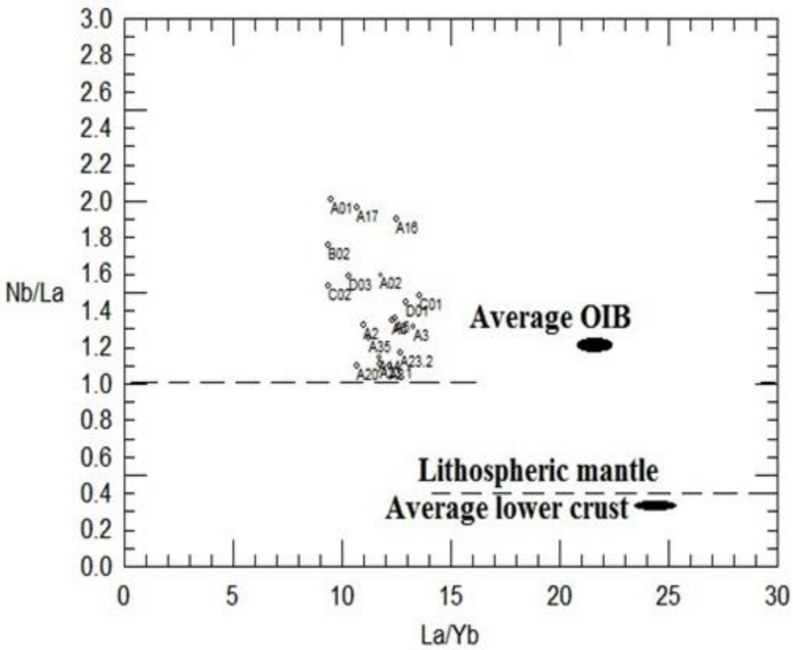

Figure. 21. The diagram of La/Yb versus Nb/La (Bradshaw, and Smith 1994) (average OIB has been given from (Fitton et al 1991) and average of Lower crust has been given from (Chen, and Arculus, 1995). Based on this figure all the samples have been originated from an asthenosphere mantle source.

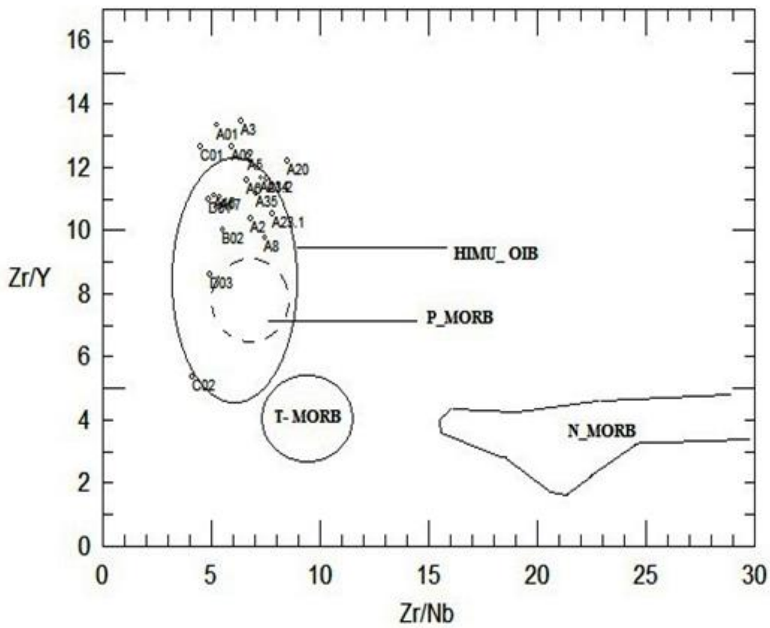

Figure. 22. Diagram of Zr/Nb versus Zr/Y OIB locations have been determined based on (Abdel – rahman and nadear 2002). TMORB and NMORB have been determined according to (Menzies And Kyle, 1990). The study samples have been located in OIB region.

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
Centro de Ciências Jurídicas - Universidade Federal da Paraíba
V. 8 - Nº 04 - Ano 2019 – Special Edition
ISSN | 2179-7137 | http://periodicos.ufpb.br/ojs2/index.php/ged/index

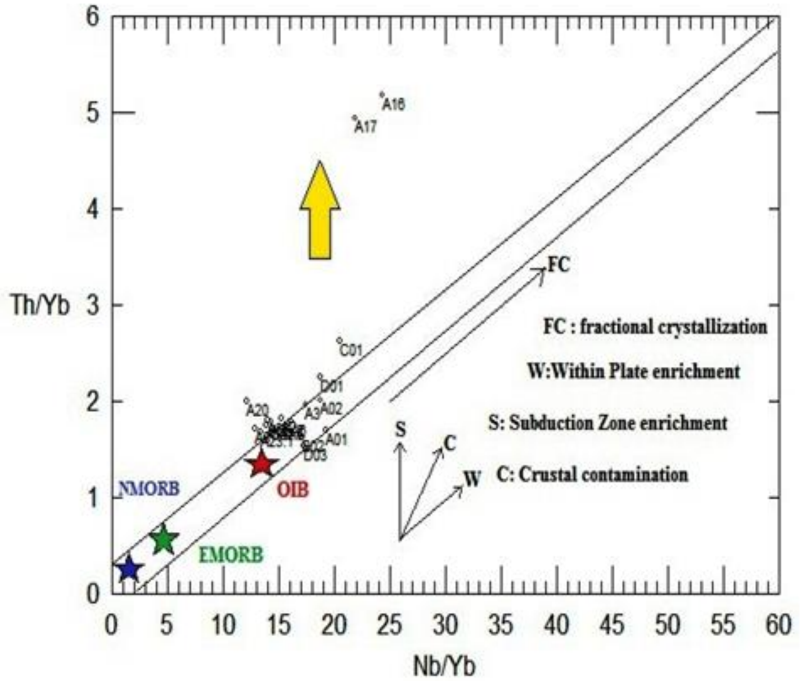

Figure. 23. The diagram of Nb/Yb versus Th/Yb (Pearce and Peate, D.W., 1995) .The samples collected from the study area have located in OIB part. It is important to notice that the two samples of A16 and A17 have been plotted farther than the other samples indicating a higher crustal contamination in these two samples. The yellow arrow shows a contamination phase.

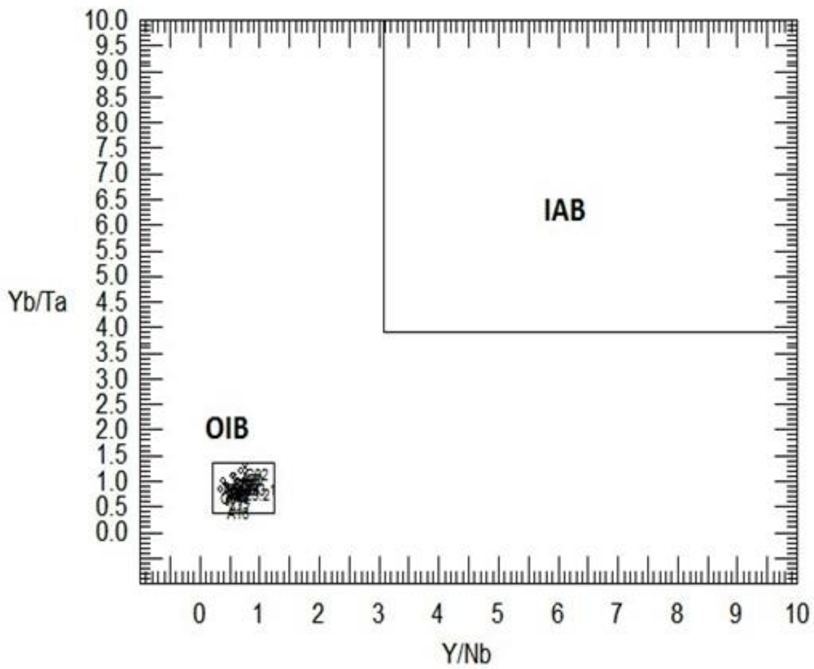

Figure. 24. The diagram of Y/Nb versus Ce/Nb (Eby, 1990) In this figure, all the study samples have been located on OIB (Oceanic Island Basalt).

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
Centro de Ciências Jurídicas - Universidade Federal da Paraíba
V. 8 - Nº 04 - Ano 2019 – Special Edition
ISSN | 2179-7137 | http://periodicos.ufpb.br/ojs2/index.php/ged/index

Contamination and tectonomagmatic environments

According to (Mojgan ,2008)'s idea, the rate of La/Nb which is more than 1.5 indicates the crustal contamination. La/Nb has a range of 0.5 to 0.91 which indicated less crustal contamination. Also, based on (Leat, 1988), the rate of La/Ta for an asthenosphere source is less than 22 indicating less contamination with crust and lithospheric mantle (Thompson and Morrison 1988) suggested that rocks with an asthenosphere source have the range of La/Ta around 10 to 12. Also the value less than 30 indicates the lithospheric or crustal contamination. The rate of La/Ta for the study rocks have fluctuated from 7.13 to 14.01. Therefore, the asthenosphere mantle is contamination free. Based on these parameters, crustal contamination has no significant role on evaluating the study rocks. However, the inconsiderable crustal contamination shows that the rate of magma ascending from the source is sufficiently high. Based on the diagram of Total REE versus (La/Yb)N containing (A) intraplate and (B) plate margin (LI, 2000), all the studied samples of Zarin-Kamar area have been located in the intraplate zone.

Intrusive rocks enriched of alkaline minerals have been mostly distributed along deep fault belts. These rocks have minerals with high concentration of REE (mostly LREE). Zarin-Kamar rocks show low values of Nb/Zr (0.117 to 0.202). The value of Hf/Sm fluctuates from 1.1 to 2.18. These rocks have been classified as potassic anorogenic rocks based on Nb versus Zr diagram (Leat et al., 1986).

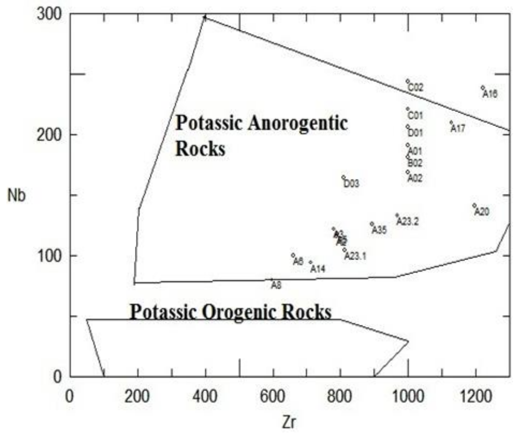

Figure. 25. Diagram of Zr versus Nb (Leat et al 1986) For the study rocks.

Periódico do Núcleo de Estudos e Pesquisas sobre Gênero e Direito
Centro de Ciências Jurídicas - Universidade Federal da Paraíba
V. 8 - Nº 04 - Ano 2019 – Special Edition
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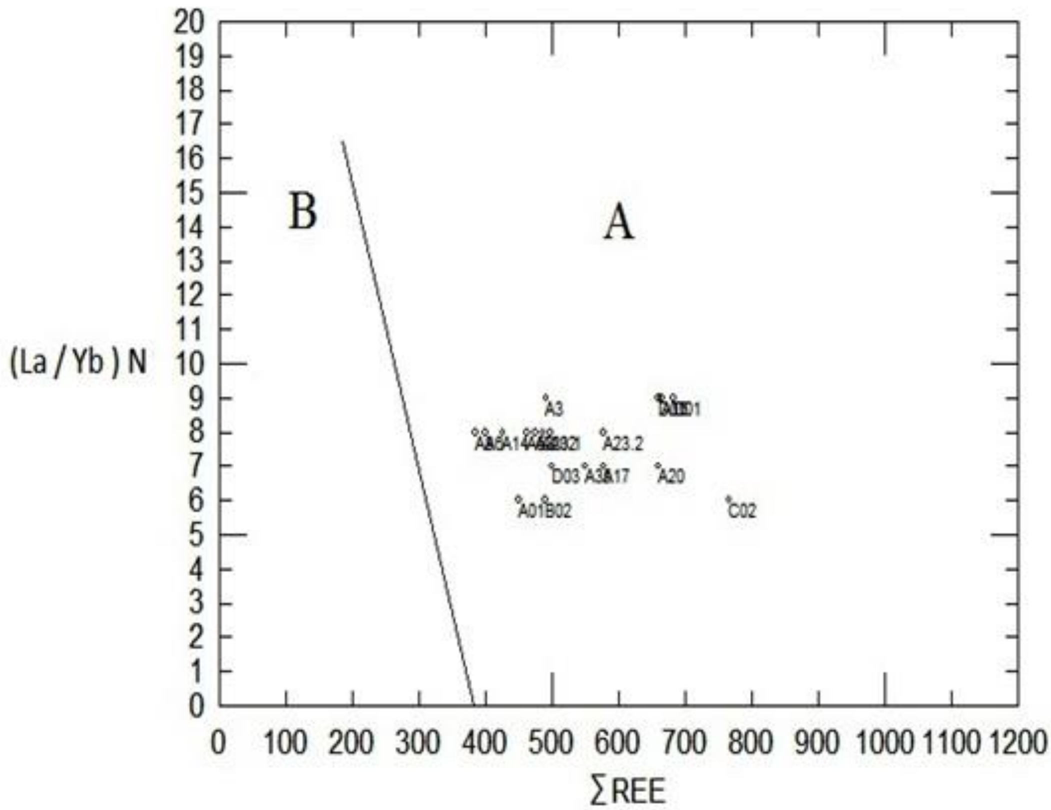

Figure. 26. Diagram of total REE versus (La/Yb)N (Li et al 2000) for the study rocks.

Conclusion

Igneous rocks of Zarin-Kamar area are mainly volcanic and plutonic. the plutonic samples are alkali feldspar syenite and quartz alkali feldspar syenite. Alkaline feldspar minerals crossing each other are dusty and gray. Aegirine pyroxene lies among them and amphibole minerals are green to gray with parallel cleavage. Alkaline feldspar minerals of the volcanic rocks in the region are elongated and narrow. These minerals have been located on a microlitic texture. Generally, they show glomeroporphyritic texture. Coarse grains show a crystallization in high depths. Fine grained microlite, however, presents a crystallization in a shallow depth closed to the surface. There is no plagioclase in the study igneous rocks.

It might have been removed during the fractional crystallization leading to a negative anomaly of Eu (Eu depletion). Fractional crystallization is a dominant process of forming the study rocks. Compared to the primary mantle, the studied samples showed depletion of Ti, P, Sr and concertation of Rb, Th, U. Negative anomaly of Ti and P can determine continental rock index and it also determines the magma contamination which was made by the bottom part of the continental crust. Based on the diagram of Y-Zr (Abu-Hamatteh, 2005), the samples were originated from a zirconium enriched mantle source. Based on the petrogenetic diagrams, the rocks of the study area are mostly OIB which a dominant process of their crystallization were fractional crystallization. The range of La/Nb is the studied rocks is 0.50 to 0.91 indicating less crustal contamination. Crustal contamination has no significant role on evaluating the rocks of the studied area. However, inconsiderate and small crustal contamination shows that the magma ascending from the source was significantly high. The studied rocks had also low values of Nb/Zr. Based on the Nb-Zr diagram (Leat et al 1986), the studied rocks have been classified as potassic anorogenic Rocks.

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Centro de Ciências Jurídicas - Universidade Federal da Paraíba
V. 8 - Nº 04 - Ano 2019 – Special Edition
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