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Petrology and Origin of Intrusive Masses of Zaker Located in NE of Zanjan

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Abstract

The study area, in east of Zanjan, with NW-SE trend exposed and structurally is located in Alborz-Azarbaijan zone and Tarom subzone. The mass composition is in monzogranite, quartz-monzonite, monzonite, quartz-monzodiorite and monzodiorite range. It belongs to high K calc-alkaline to Shoshsonitic magmatic series. According to the geochemistry and petrogenesis results, partial melting of magma has been the important controlling process of rock variety in the study area. All samples have negative anomalies of Nb that is related to subduction and active continental coastline zones as well as high anomalies of K, Rb and Ba explaining the role of continental crust or contamination with the continental crust. Granitic volcanic arc related environments and syenite alkali feldspar masses reflect the granite mass within the plate. Monzonites and diorites point to the volcanic arc and syenite and granite masses show within the plate environments.

Keywords

Petrology, Granite, Alborz, Partial Melting, Iran

1. Introduction

The study area (Zaker granite) is located in 16 km from NE of Zanjan and between 48˚29'E to 48˚53'E geographical longtitudes and 36˚33'E to 36˚45'E latitudes. Zaker granite is situated in the central part of the 1: 250,000 map of Zanjan (Figure 1) and the southern half of the 1:100,000 map of Tarom. In the geological zoning of Iran, the study area is a part of the Quaternary-tertiary magmatic belt of Western Alborz [1]. The belt has attracted the attention of many domestic and foreign researchers due to geological surveys and mineral studies [2].

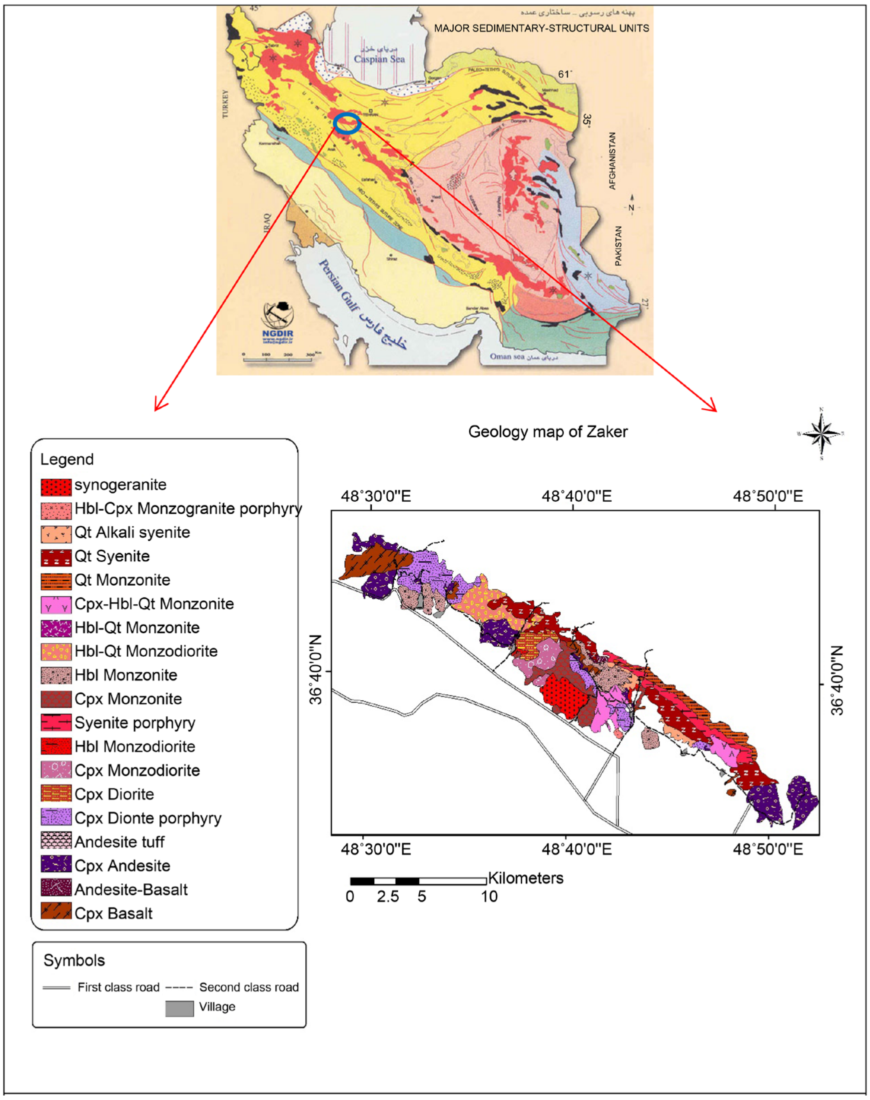


Figure 1. 1:25,000 map of Zaker granite.

2. Stratigraphy

From the perspective of structural geology and sedimentary structural zones of Iran, two tectonic territories are dominant in the province of Zanjan. The northeast of the province (Tarom Mountains) is a small part of the southern slopes of Alborz, while the vast expanse of the central and southern parts of the province belongs to the plate of Central Iran. Geological evidences indicate that the boundary between the two zones passes through Qavyn, Abhar, Zanjan plain.

Magmatic intrusions of granite and coarse-grained granodiorite masses are from the typical geological characteristics of the magmatic highlands of the northern part of the province that have been injected to the Eocene volcanoclastic complexes (Karaj formation).

Hence the masses have Eocene age and according to the regional evidences, a part of the intrusive rocks belongs to the Pyrenean orogeny that has been injected through the length and depth of the structures and faults of Tarom heights. One of the properties of the intrusive rocks after Eocene is alteration halos in Eocene volcanoclastics that generally its hydrothermal phases has been accompanied with forming elements such as epithermal gold, copper, lead and zinc, kaolin and etc.

Intrusives of Tarom sheet are often semi-deep and in some cases deep. Porphyric textures, variable sericitic, argillic, and propylitic alterations in marginal sectors of the intrusives and on the other hand, poor thermal effect on adjacent rocks (in the alteration extent or in some cases in the albite-epidote-hornfels facies extent) show shallow setting of most Tarom sheet intrusives.

The masses have petrological variety from gabbro, monzonite and granodiorite and even alkaline granite that exposed in Karaj Formation in the area [3]. According to the injection into the Karaj formation, the age of these masses attributed to the Oligocene [4]. The general trend of the geological structures, as well as other areas of the West Alborz is NW-SE.

3. Petrography

Petrographically, the granitoid masses of the area change in lithological composition as diorite, monzonite, syenite and granite.

3.1. A-Diorites

The unit contains pyroxene diorite, pyroxene monzodiorite, hornblende monzodiorite and hornblende quartz monzodiorite rocks. They spread in the center of the study area. The main texture is granular and the secondary texture is myrmekitic and graphic (**Figure 2(b)**). Mineral constituent is plagioclase-pyroxene-quartz-hornblende and orthoclase (**Figure 2(a)**), whereas the minor minerals include chlorite, epidote, clay minerals and zeolite. The existence of minor minerals such as tourmaline, zircon and apatite is from the unit features. The unit shows weak propylitic alteration.

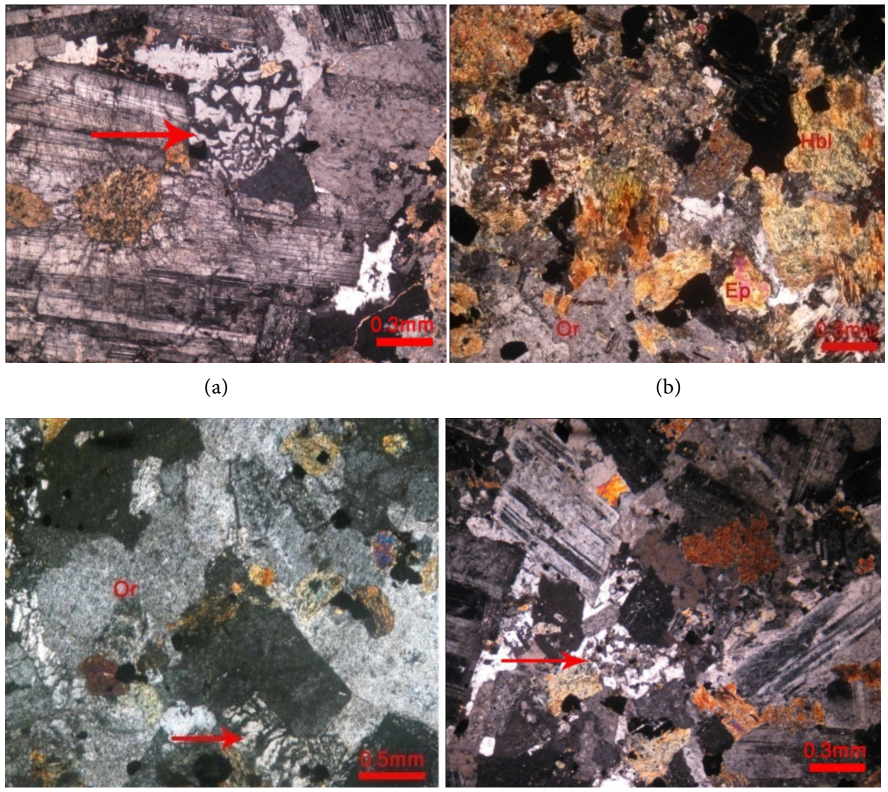
3.2. Monzonites

The unit contains pyroxene monzonite, hornblende monzonite, pyroxene hornblende quartz monzonite and quartz monzonite rocks .The main texture in the rocks is granular and from the secondary textures can point to graphic, myrmekite and poikiloblastic textures (**Figure 2(c)**).

This unit consists of minerals such as plagioclase-orthoclase-clinopyroxene (diopside)-hornblende-quartz and biotite that are seen in some thin sections (**Figure 2(d)**). In some parts of the unit, weak argillic alteration, weak propylitic to epidote alteration, weak argillic alteration and weak propylitic alterations are seen. Zircon and apatite are the minor minerals in the unit.

3.3. Syenites

This unit consists of quartz syenite and alkali syenite. The unit with NW-SE trend has extended in the study area. In hand specimen, the unit color is light



(a) (b) (c) (d)

Figure 2. (a) View of epidote, orthoclase and hornblende minerals in pyroxene diorite unit (XPL light); (b) view of graphic texture in hornblende monzodiorite (XPL light); (c) view of graphic textures in pyroxene monzonite (XPL light); (d) view of orthoclase alteration to clay minerals and graphical textures of hornblende monzonite (XPL light).

gray to pinkish. The unit texture is granular in microscopic studies and includes orthoclase, quartz and plagioclase minerals (Figure 3). The unit shows too weak argillic alteration and epidote veinlets have been observed with a thickness of 2.0 mm in some parts. Zircon and apatite are the minor minerals of the unit.

3.4. Syenogranite Unite

This unit outcrops in the north of the study area.The alkali feldspaths percent in this unit is far more than other units. Granular and graphic textures are the index textures of the Syenogranite unite. The unit minerals include: orthoclase, quartz, plagioclase and often shows albite twinning.

Hornblende is rarely and with a frequency of 2% detected in the unit. Zircon is the minor mineral of the unit. The unit shows the weak argillic alteration in some parts and abundant epidote-zoisite veinlets are seen in some areas. The thickness of the veinlets varied between 0.2 to 1 mm.

4. Geochemistry

The chemical analysis results of 18 rock samples of Inductively coupled plasma mass spectrometry method (ICP-MS) were used that were analyzed at Acme of Canada. Also, to determine the name of rock after microscopic studies, XRF

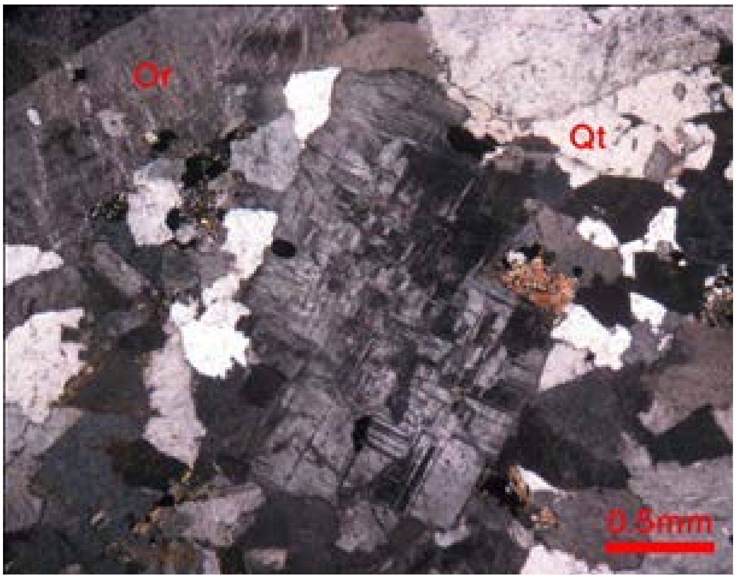


Figure 3. View of the quartz and perthite orthoclase minerals (XPL light).

analysis was done in former company of Spectrum Binalood Deposits or Aimetis Of The East.

The selected samples of intrusives in the Middlemost (1985) [5] classification diagram is located in monzonite to quartz monzonite and in normative classification of Barker (1979) [6] is in the areas of tonalite, granodiorite, and Granite (**Figure 4(a)** and **Figure 4(b)**).

In the Shand (1994) diagram [7], granitoid rocks are within metaluminous range and in Peccerillo and Taylor, (1976) diagram [8], are in the high Calc alkaline and shoshonite range (**Figure 5(a)** and **Figure 5(b)**).

Researcher's studies have shown that the amount of alkaline elements increasing in after the collision rocks is due to asthenosphere magma entering into the final stages of magmatism and according to the partial melting and crust contamination, we have different types of rocks with alkaline nature in these areas [9].

Granitoid samples are normalized compared to the upper continental crust and chondrite (**Figure 6(a)** and **Figure 6(b)**). Trace elements pattern of arc magmas, when are normalized to chondrite or MORB, is like this that arc magmas show enrichments of LREEs(Light rare earth elements) and LILEs (Heavy rare earth elements)such as La, Ce, Nd, Rb, K, Cs and depletions of HREEs and HFSEs such as Yb, Lu, Nb, Ta, Zr, Hf.

This feature is called arc-signature. This feature is created through corporate behavior of trace elements among main manufacturers of peridotite (olivine, pyroxene) or eclogite rocks (omphacite, garnet) of subducted and fluid oceanic lithosphere during dehydration reactions of hydrous silicates [10] [11].

In the normalized graph of plutonic rocks into the upper crust can be seen that the K, Sr, P elements have positive anomalies and Nb and Tb show negative anomalies (**Figure 6(b)**). In this graph be specified that granite and quartz alkali feldspar syenite masses do not follow the others trend. This unit shows increasing

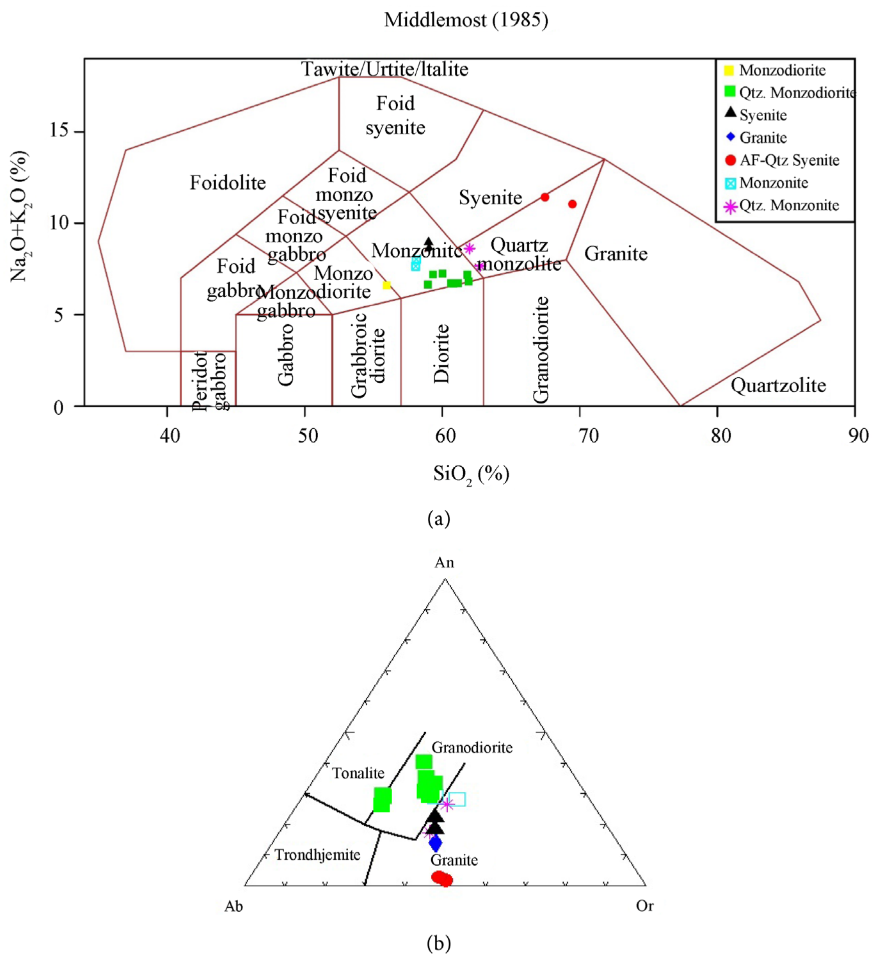
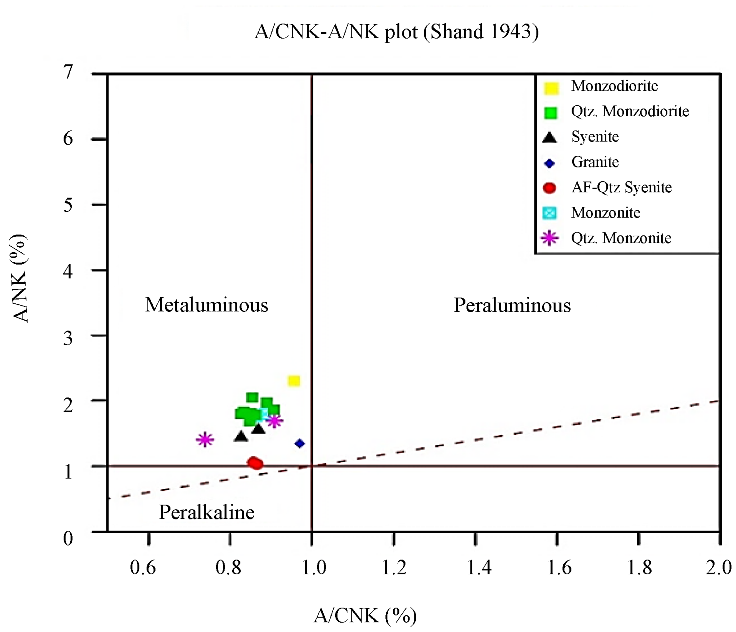


Figure 4. (a) Classification of intrusive igneous rocks of the area using (Middlemost, 1985a) diagram [5]; (b) The area intrusives classification based on normative composition (Barker, 1979) [6].

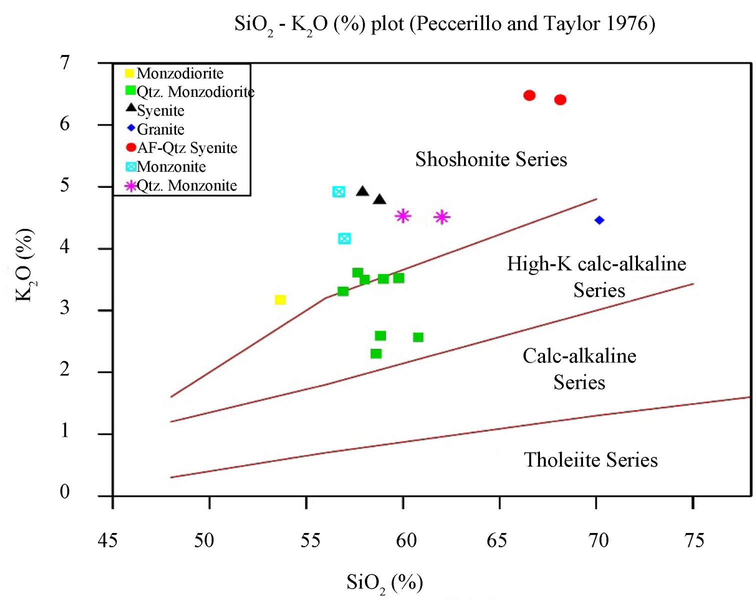
in the amount of Zr and Hf that could result from the abundance of the zircon mineral in the masses.

Eu negative anomaly is as a result of separation of plagioclase or k-feldsapat from felsic melt or by crystal fractionation or partial melting (which feldspar remains in the slag). Eu positive anomaly is also due to feldspar accumulation [12]. Lack of both negative and positive anomalies indicates that plagioclase crystallization has not an important role in the evolution of magma crystallization and only it is may be incurred high pressure prior to translocation at higher levels [13] (**Figure 6(a)**).

In Zaker granites, large Ion lithophile elements such as Rb, K and Ce show a clear enrichment and relative intense field elements such as Nb, Ti, Y, and Yb show the lowest enrichment (**Figure 6(a)**). This is one of the features of volcanic arc granitoids related to subduction zones. The negative anomaly of Nb is index for the areas that is related to the subduction zones and the continental active coasts. In the normalized graph of plutonic rocks into the upper crust, can be seen that K, Sr, P elements show the positive anomalies and Nb and Tb show the



(a)



(b)

Figure 5. (a) A/NK-A/CNK) diagram, (Shand, 1943) [7] to determine the degree of saturation of alumina in igneous rocks of the study area; (b) Peccerillo and Taylor diagram, -1976 [8] positioning of the samples in calc-alkaline series.

negative anomalies (**Figure 6(b)**). The diagram indicates (**Figure 6(b)**) that granitic quartz alkali feldspar syenite masses do not follow the others. The P enrichment can be attributed to the presence of abundant apatite phase. Also, apatite can control the enrichments of U, Y, Th and REE [14].

The rocks show the depletion of Nb, Zr elements. Zr element does not readily enter into the main minerals but can be replaced instead of Titan bearing minor minerals [15] and the anomaly of titanium element is justified by differentiation

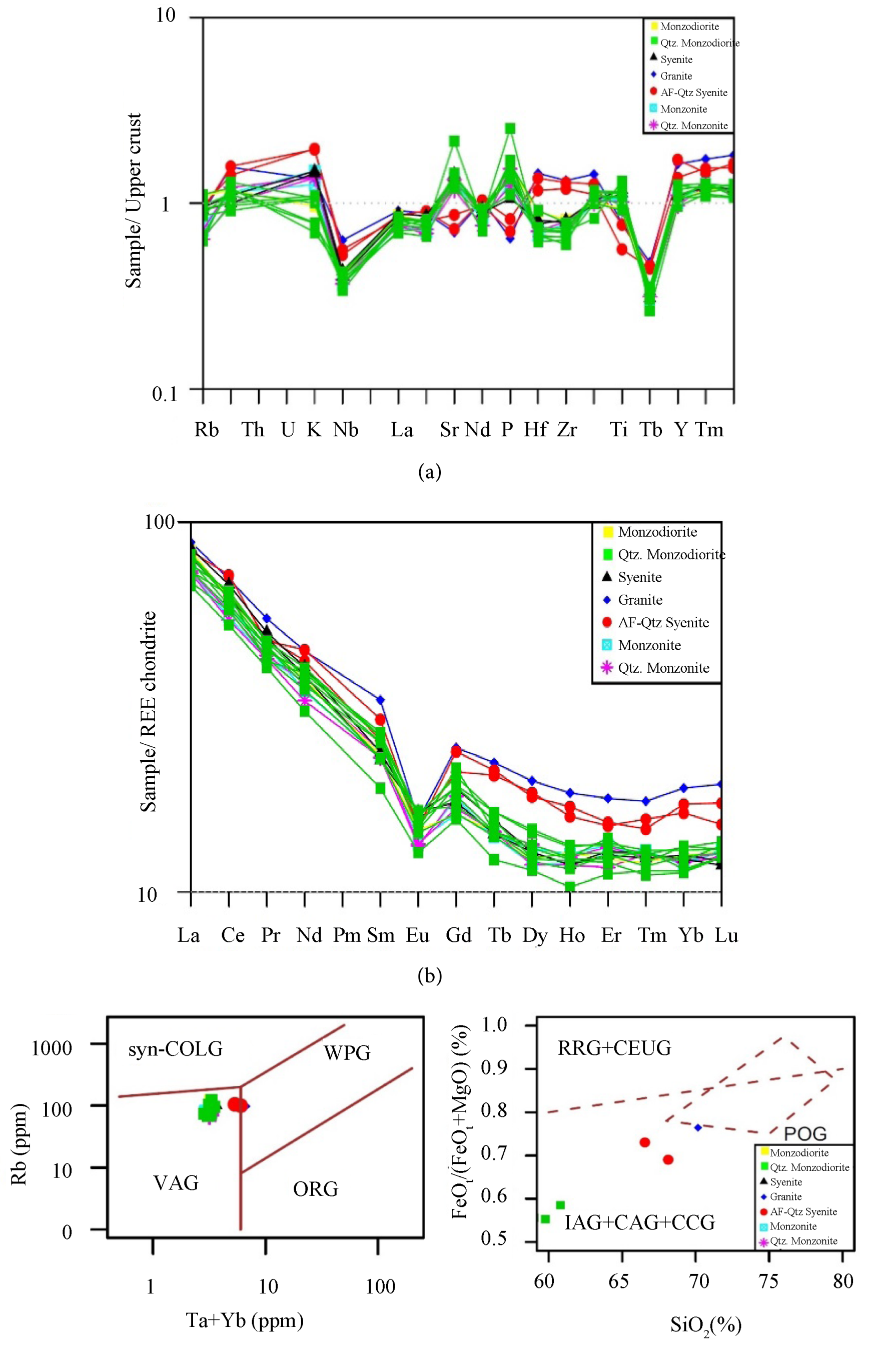


Figure 6. (a) Normalized diagram of intrusive rocks of the area into the chondrite- (Boynton, 1984) [16] for granite Sample; (b) Normalized diagram of plutonic rocks of the area into the upper crust [17] (Taylor and McLennan, 1985). Diagram of tectonic setting determination of granitoids (Maniar and Piccoli, 1989) [18]; (d) Separator diagram of granites based on-Rb – (Yb + Ta), (Pearce et al., 1983) [19].

of titanium bearing phases such as Titanite, Titano-magnetite and so (**Figure 6(b)**).

Also, in the FeOt/FeOt + MgO to SiO_2 diagram (**Figure 6(c)**) the samples fall in the-IAG + CAG + CCG range. Based on the obtained information from these diagrams and geotechnique of the area, most possibly, granitoids of the area (most of the intermediate composition rocks of the area) are from CAG continental margin type and post-orogenic (POG) (granitic and alkali feldspar quartz syenite rocks that are available in the study area).

Also the Rb − Yb + Ta diagram confirms the obtained results (**Figure 6(d)**). In this diagram, majority of samples place within the volcanic arc granites (VAG) range, while have a trend into the inter plate environments (WPG).

The difference between inter plate granites and the post continental-collision granites is in the amount of Ba element. In this way that the inter plate granites have negative anomaly of Ba unlike the post-collision granites.

Although the granite and quartz alkali feldspar syenite masses of the area have been in the WPG environment, but because do not show negative anomaly of Ba, so they can be considered as the post-collision granites.

5. Petrogenesis of Rocks of the Area

Based on the Zr-Y diagram (Abdollah *et al.*, 1997) [20], in the partial melting phenomenon (PM), along with the increase of Zr value, Y reduced. While in the fractional crystallization phenomenon (FC) changes of Zr value to the amount of Y have direct proportion and with increase of Zr, the value of Y increases (**Figure 7**).

This diagram (**Figure 7**) for the samples of the study area shows the role of partial melting in the evolution of the area rocks (regardless of granite and alkali feldspar quartz syenite for having a different origin).

Determination of Partial Melting Degree of the Source Rock of the Intrusive Rocks

In the diagram that has been normalized into the chondrites [16], LREE (Light rare earth elements) shows enrichment than HREE (Heavy rare earth elements). This Enrichment is due to the low percentage of partial melting of the source rock. To prove that the rocks of the area formed from low levels of partial melting,

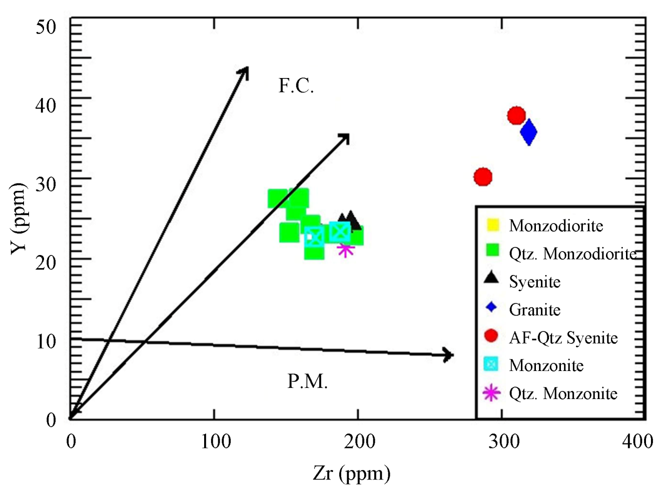


Figure 7. Zr-Y diagram (Abdollah *et al.*, 1997) [20].

we have used the below graph.

In the La/Sm vs La [21], degree of partial melting is close to 5% and from a Lherzolite garnet source (**Figure 8**). Thin solid lines in the diagram represent the changes trends of melts that have derived with different degrees of partial melting from spinel Lherzolite and dashed lines indicate melts that have originated from partial melting of garnet Lherzolite. On the thick line, depleted and enriched primary mantle range has been specified.

6. Tectonic Setting

At Eocene-Oligocene time, simultaneous with the Pyrenees tectonic phase, Eocene and older deposits have folded and shallow intrusive masses have placed within them aligned with the structural trend. Intrusive masses that often are shallow, causes slope changes of the layers in their vicinity due to uplifting. The elongation trend of their outcrops follows the two N58w and N12w procedures and in some cases N45E.

In Tarom subzone (study area) (pyroclastic and lava deposits of Eocene have formed anticline and syncline with a thickness of approximately 2 to 4 km and the axis of the anticlines and synclines are often steep.

The Oligocene intrusive bodies have cut the Eocene rocks along NW-SE and would have been altered at the margin. High thick of the row of the intense volcanic activity in Eocene, existence of Oligocene numerous and oriented intrusions and absence of any trace from old basement is characteristic of this subzone.

7. Conclusion

The igneous units are in six group of mass: Monzonitic (hornblende monzonite, Pyroxene monzonite, hornblende quartz monzonite, Pyroxene hornblende

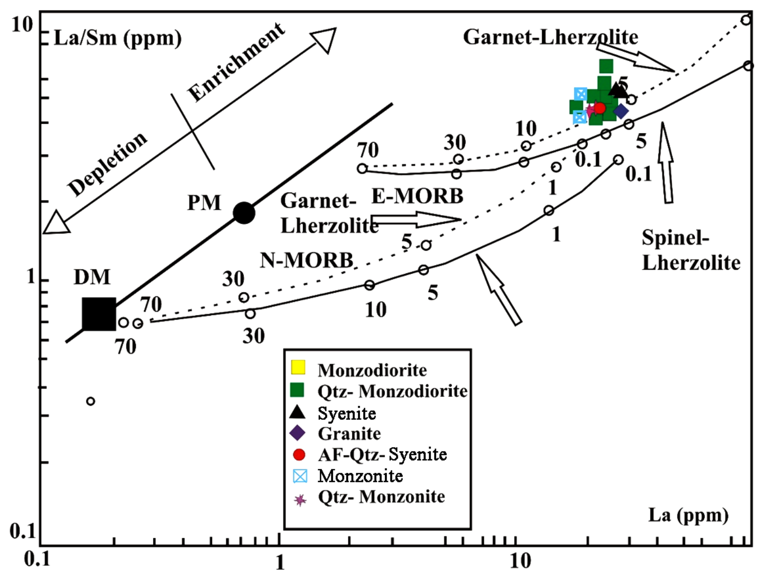


Figure 8. The La vs La/Sm diagram in order to calculate the partial melting value of the source rock of the intrusive units (Aldonmaz *et al.*, 2000) [21].

quartz monzonite and quartz monzonite), Monzonite masses (pyroxene monzodiorite, hornblende monzodiorite, hornblende quartz monzodiorite), pyroxene diorite, quartz syenite, syenogranite and alkali feldspar quartz syenite. The Zaker granite, large ion lithophile elements such as k, la, Ce, Rb enrichment and Nb, Ti, Y, Yb elements show depletion that is the feature of volcanic arc granitoids related to subduction zones. The patterns of rare earth elements and the mass nature of quartz syenite and granite is slightly different from the diorite and monzonite masses that this reflects differences in magmatic processes and probably syenite and granite masses which were formed after collision and in more delayed stages than diorite and monzonite intrusives.

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