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PETROLOGY AND TECTONO-MAGMATIC ENVIRONMENT OF THE VOLCANIC ROCKS OF SOUTH MARZAN ABAD, CENTRAL ALBORZ MOUNTAIN

PETROLOGIA E AMBIENTE TECTONO-MAGMÁTICO DAS ROCHAS VULCÂNICAS DO MARZAN ABAD SUL, MONTANHAS CENTRAIS DE ALBORZ

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ABSTRACT

Structurally, the study area belongs to the Central Alborz tectonic range. The volcanic rocks in the region, composed of basalt, andesite, trachyandesite and dolerite, have been formed by fractional crystallization and, in some cases, contamination processes. The major minerals in the rocks include clinopyroxene, olivine and plagioclase. Porphyritic to mega-porphyritic textures with chlorite, glomeroporphyritic and amygdaloidal matrices are observed in the rocks. In general, the regional rocks are rich in LIL and LREE elements and depleted of HFS elements. Evaluation of the ratios of rare and rare-earth elements indicates that the basalts in the region may be formed through partial melting of a garnet peridotite at high depths and pressures. The negative Ce anomaly, the positive Nb anomaly and the Pb/Ce ratio similar to that found in the OIB sources and diversity of the Ce/Pb ratio emphasize the role of continental and mantle lithosphere in the contamination of magmatic sources of elements in the volcanic rocks found in the study area. Therefore, delamination and detachment of the lithosphere and its sinking in the mantle (due to density difference) and the transfer of the dense lithosphere to high depths (lower mantle) can be related to contamination of the magmatic source with the lithosphere for the primary magma of the volcanic rocks in the intraplate range.

Keywords: Volcanic Rocks; Intra-Continental Plate; Marzan Abad; Iran..

RESUMO

A área de estudo pertence estruturalmente à faixa tectônica de Alborz Central. As rochas vulcânicas da região, compostas de basalto, andesita, traquandandita e dolerita, foram formadas por cristalização fracionada e, em alguns casos, processos de contaminação. Os principais minerais nas

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rochas incluem clinopiroxênio, olivina e plagioclase, texturas porfiríticas a mega-porfiríticas com matrizes de clorita, glomeroporfirite e amigdaloidal são observadas nas rochas. Em geral, as rochas regionais são ricas em elementos LIL e LREE e empobrecem os elementos HFS. A avaliação das proporções de elementos raros e de terras raras indica que os basaltos na região podem ser formados através do derretimento parcial de uma peridotita granada em altas profundidades e pressões. A anomalia Ce negativa, a anomalia positiva de Nb e a razão Pb / Ce semelhante à encontrada nas fontes OIB e a diversidade da razão Ce / Pb enfatizam o papel da litosfera continental e do manto na contaminação de fontes magmáticas de elementos no vulcão, rochas encontradas na área de estudo. Portanto, a delaminação e descolamento da litosfera e seu afundamento no manto (devido à diferença de densidade) e a transferência da litosfera densa para altas profundidades (manto inferior) podem estar relacionados à contaminação da fonte magmática com a litosfera para o magma primário das rochas vulcânicas na faixa intraplaca.
Palavras-Chave: Rochas vulcânicas; Placa intra-continental; Marzan Abad; Irã.

INTRODUCTION

The Alborz mountain in north of Iran is part of the Alps and the Himalayas, which has formed a high mountain arc with a length of about 600 km and a width of 60 to 120 km. This mountain has Several peaks with a height of 3600 to 4000 meters. Its highest peak is Damavand volcanic mountain (AXEN *et al*. .,2000) which is bounded from the north to the Caspian depleted Block, from the south to the Central Iran Plateau, from the west to the Caucasus heights, and from the east to the Afghanistan mountains (ALAVI , 2000) . One of the important features of the Alborz Mountain is the lack of a regional metamorphic zone as well as a thin lithosphere with a thickness of about 35 km (TATAR *et al.*, 2002; ANSARI , 2013; ZANCHI *et al.*, 2006). This mountain forms a drift belt, which is part of the active divergence within the vast Eurasia - Saudi Arabia zone (JACKSON, 1992; CUNHIGHAM *et al.*, 1996; ALLEN *et al.*, 2003; HARLAND, 1971; VAUCHEZ and NICOLAS , 1991; HAYNES and MAQUILLAN , 1989). This belt was created at the end of the Simerin orogeny (Late Triassic) from the collision of the Iranian block with Eurasia (ANSARI, 2013) (Figure 1).

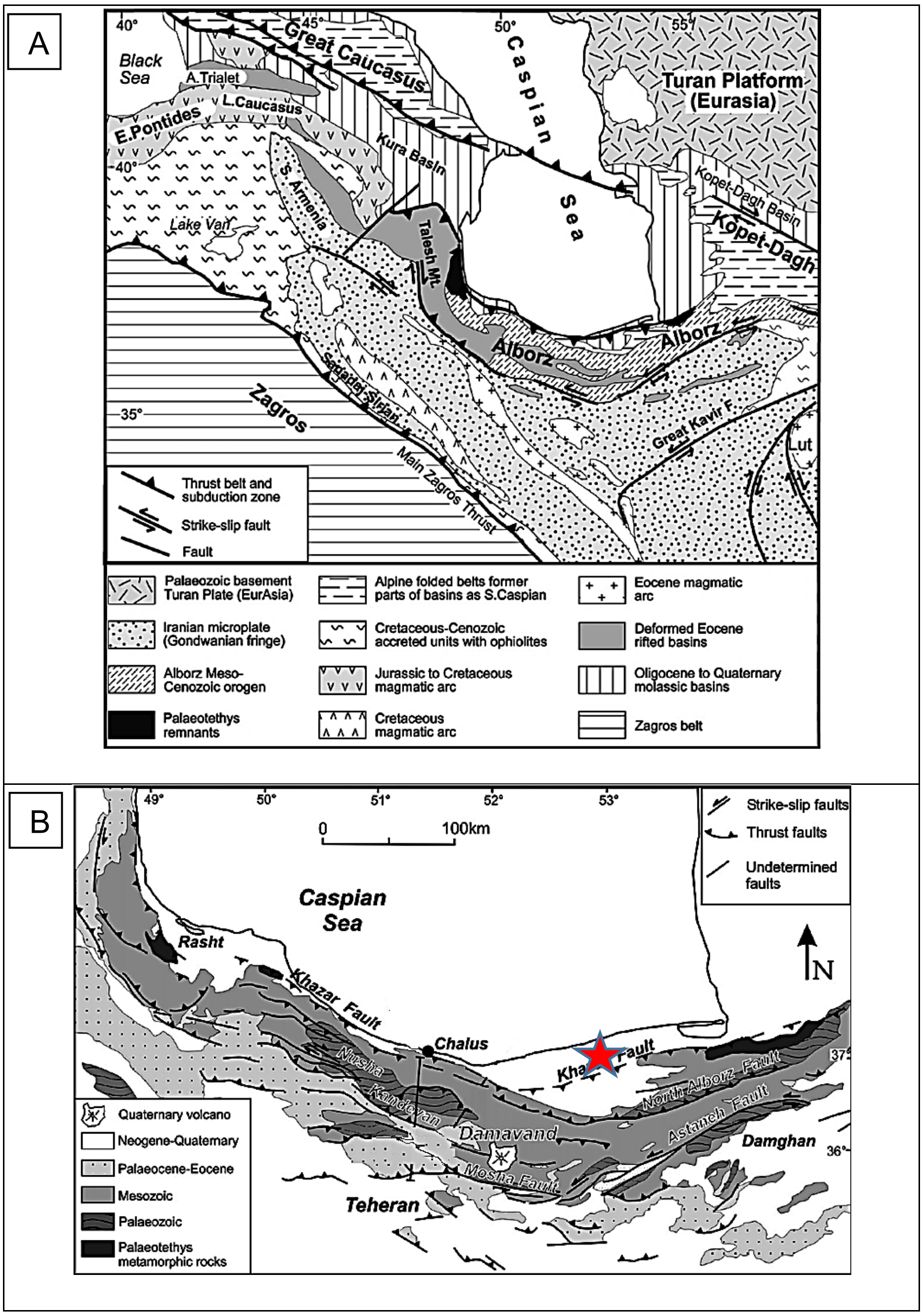

Figure 1. (A) General tectonic map of North Iran and of the South Caspian region (Brunet et al,2003). (B) Tectonicmap of the Central Alborz
Source: Modified from Allen *et al*. (2003) and Zanchi *et al.* (2006).

The active deformation of the Iranian Land, as a branch of the Alpine-Himalayan Orogenic Belt, can be related to the convergence of the Arabian Plate with south Asia and the movement of the South Caspian Plate. Alborz Mountains in the north of Iran include a long seismic belt with a length of 900 km in the South Caspian Basin (SCB) linking the Caucasus and Talesh Mountains in the northwest and west of Kopet Dagh and Binaloud Mountains in the northeast and east of Iran Plateau (BERBERIAN , 1983; ALLEN *et al.*, 2003b; JACKSON, 2006).

After the Early Cimmerian compressional orogenic event in the Central Alborz, the onset of Mesozoic extensional phases is specified by the Upper Triassic Rift Volcanism (Rhaetic) and deposition of the Shemashak Coal Formation (BERBERIAN, 1982). Therefore, the Central Alborz has been affected by extensional tectonics before the formation of the Shemshak Formation during its deposition indicating the insignificant impact of the Cimmerian orogenic phase (FURSICH *et al.*, 2005; ZANCHI *et al.*, 2005, 2006; BERRA *et al.*, 2007).

After the Late Cretaceous Compressional Phase, a major extensional phase occurred throughout Iran (except for Zagros and Kopet Dagh) causing a severe Eocene volcanism in most parts of Alborz-Azerbaijan.

A Permo-Triassic accretionary-subduction complex marking the Paleotethys suture between the Turan and the Iranian plate has been recognized in the Mashad and Torbatjam regions to the east (RUTTNER, 1993).The Upper Triassic succession is almost continuous (GHASEMI-NEJAD *et al.*, 2004; YAZDI *et al.*, 2019a) and is marked by a sudden change in sedimentation, from shallow sea carbonates to silicilastic sandstones, suggesting that central Alborz was located south of the main suture zone and then behaved as a stable foreland region during the collision (ANSARI, 2013).

The Central Alborz includes the southern convexity of the Caspian Sea and extends from Semnan to Qazvin. The study area is located 25 km from the south of Chalus between 51’ 00° and 51’ 15° east longitudes and 50° 36’ and 41’ 37” north latitudes. Like most other areas, the geomorphology of the region is influenced by the facies of rock units, the axis trend of folds and type of fault mechanism. In a general perspective, the region has been created of an anticline with a west-northwest axial direction with an axial inclination to the west and southwest. This volcanic unit has been made of Cretaceous carbonate units in the southwest with a normal boundary (border) with the Lower Cretaceous carbonate units. Therefore, this volcanic unit has a clear boundary (border) with the Middle-Upper Cretaceous carbonate rocks.

Cretaceous rock of this sedimentary sequence in the chalous Vallye are al so know as the chalous formation by (CARTIER ,1971), which emerged in the northern part of the central Alborz in the late cretaceous. The sequence of carbonate- volcanic rocks in the southern part of. The Alborz is covered with paleocene's Conglomerate sediments (Fajan formation). Eocene carbonate sediments have also been deployed overlaping on older rocks in southern parts of the central alborz region (GEOLOGICAL SURVEY OF IRAN, 1991; ALLEN *et al.*, 2003).

Ziyarat Formation in the western parts has a northwest – southeastern direction and in the eastern parts has a hortheast – southwest direction. The alighment of the structures at both ends of the mountain changes and turns into talesh drift belt in west and kopet dagh in the east. (BERBERIAN, 1997; JACKSON *et al.*, 2002) the mountain slopes on both sides of the North and south have a steep slope and suddenly lead to adjacent plains along the main faults. (BERBERIAN AND YEATS, 1991) the forehead structures on both sides go forward to these basins (ALLEN *et al.*, 2003).

A majority of volcanic rocks in the region belong to the Lower-Middle Cretaceous in the range of alkali olivine basalt, alkali basalt, basaltic andesite, basalt andesite, pyrite, basaltic tuffs, agglomerate, autoclastic and epiclastic breccias such as volcanic sandstones with carbonate cement and round-elliptical coarse-grained volcanic conglomerates, and clastic rocks are also observed with a layered (laminate) appearance and pillow lavas in some cases.

ANALYTICAL METHODS

A total of 70 samples from the igneous rocks of the Troud complex were collected, in which 35 thin sections were studied by a polarized microscope. Fourteen representative samples were then selected for whole-rock chemical analysis. Samples weighed between 1 and 1.5 kg before crushing and powdering. Whole-rock major elements were determined by an X-ray fluorescence (XRF) spectrometer and trace and rare earth elements (REEs) were determined by lithium metaborate fusion ICP-MS at the GSI laboratory in Thran, Iran.

DISCUSSION

PETROGRAPHY

The volcanic rocks of the studied area are divided into several rocky basaltic rocks, which are mainly composed of the minerals of Pyroxene + Plagioclase + Olivine + Dark minerals as mineral. The tissues of these rocks are mainly porphyritic With microgranular pulp (Figure 2a-b). The tracy basalt family of tragic rocks is predominantly of porphyritic texture with microleaky dough and its main mineral consists mainly of androgenetic plagioclase + pyroxene + olivine as the minor minerals of these rocks (Figure 2c), Andesitic rocks is predominantly plagioclase + Amphibole , and the dominant texture of these rocks is a prophylaxis with microlytic droplets (Figure 2d), dolerite rocks containing plagioclase + pyroxene + Olivine + Dark minerals have been created as subterranean minerals, and the dominant texture of these rocks is a prophylaxis with microlytic droplets (Figure 2e-f).

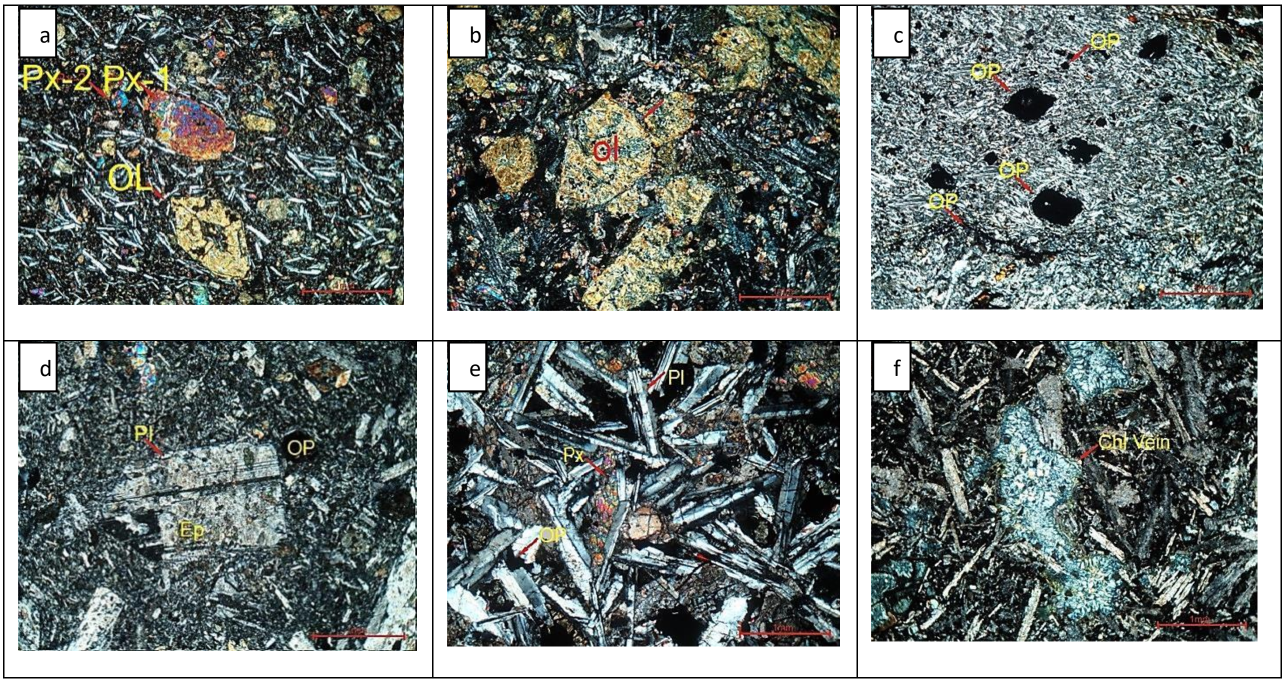

Figure 2. Microscopic sections of volcanic rocks belonging to the Great Cataract Formation of the Chalus Formation, (*a,b*): basalt, olivine (with Iddengsite edges), pyroxene (px) (Ti, Aug), plagioclase (Pl) (andesin), op (plane-polarized light). (*c*): Trachy andesite, plagioclase (Pl) (Albite) Olivine (olv),Pyroxene (Px), Plane polarized light, Dark minerals (op) (plane-polarized light).(*d*): Andesite, plagioclase(Pl)(andesin), Amphibole(Amp).(*e, f*): dolerite, pyroxene (px), plagioclase (Pl) Oligoclase-andesin (Olivine , op (plane-polarized light).
SOURCE: PLEASE INSERT THE SOURCE OF THE FIGURE.

GEOCHEMICAL ANALYSIS OF VOLCANIC ROCKS

According to geochemical analysis of the major elements, most volcanic rocks in the region are of the basic and alkaline types. Also, in the TAS (Le Bas *et al*., 1986) diagram, most specimens are located in, trachy Basalt, Basalt trachy andesite and Basalt (Figure 3b). In the TAS (COX *et al.*,1979) diagram, most specimens are located in,Basalt and Hawaiite (Figure 3a).

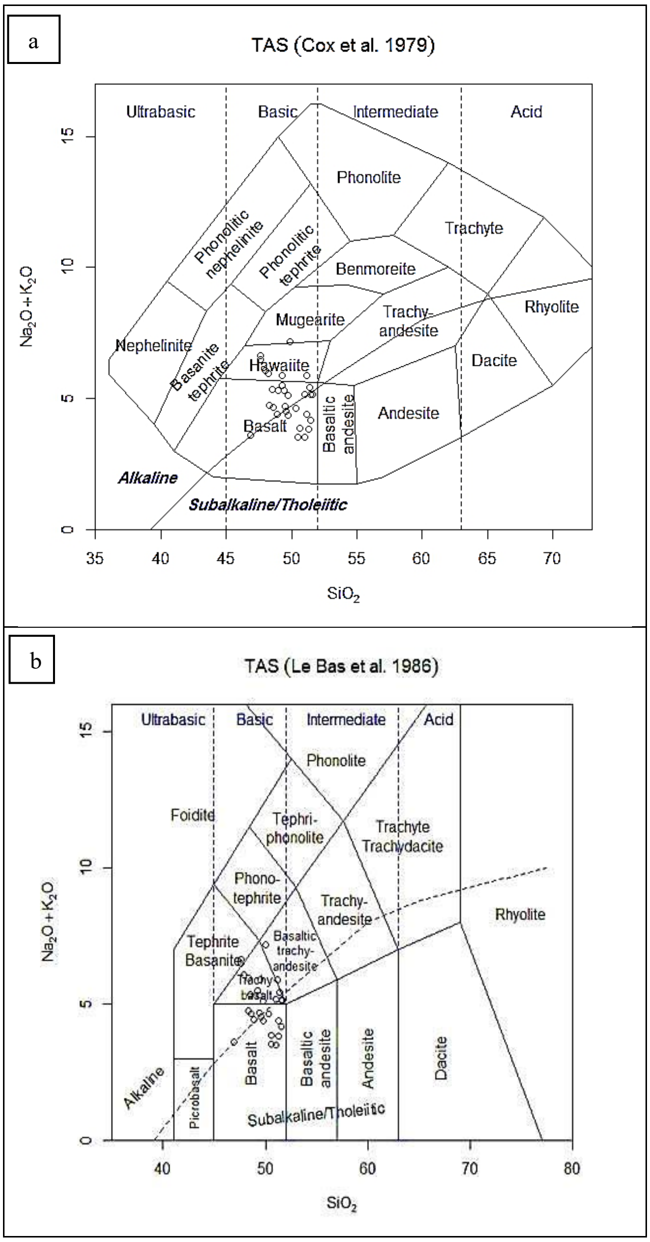

Figure 3. (a) Classification alkali basalt samples in the TAS diagram with alkaline sub-alkaline magma series. (b) Classification alkali basalt samples in the TAS diagram with alkaline sub-alkaline magma serie.
Source: COX et al. (1979). Le Bas et al. (1986)

The Zr / TiO2 diagram versus Nb / Y quoted indicates that most of the conductors are ALK-Bas, Basanite- nephleen (Figure 4a) The Nb/Y diagram versus Zr/Ti quoted from (MODIFIED and PEARCE ,1996) indicates that most of the conductors are Alkali basalt and Foidite (WINCHESTER and FLOYD,1977) (Figure 4b).

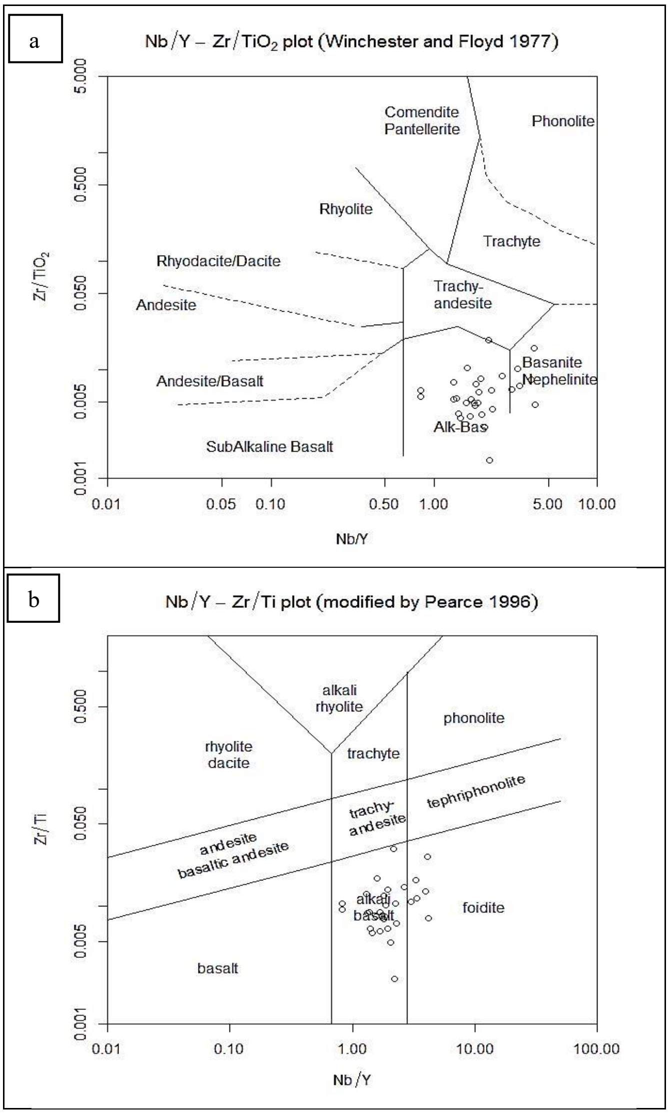

Figure 4. (*a*) Nb/Y–Zr/TiO2 diagram showing the alkaline volcanic Rock; (*b*) Nb/Y- Zr/Ti diagram
Source: Winchester and Floyd (1977); Modified from Pearce (1996).

The geochemical investigations of the studied area show an enrichment in the HFSE, LILE, and REE of the elements of the original mantle, normalized mantle, indicating that they originated from the origins of the parental magma of the archipelago OIB (ANSARI, 2013). The normalized mantle diagram of Thomposon (1982) shows a relative correlation that increases from left to right and positive anomalies Nd,Ti, Th, La and negative anomalies of Tm, Sm,sr,Rb and the enrichment of compatible elements and LILE elements relative to Kenndryte are quite visible.also normalized mantle diagram of Sun and McDonogh (1989) show that positive anomalies Nd,Ti, Th, La and negative anomalies of Tm, Sm,sr,Rb and negative anomalies of Rb,U,Ba,K,Ce,Zr,Ti and Strong depletion in sr (70 to 1100 for the primary mantle) is shown in the rocks of the study area (Figure 5-7).

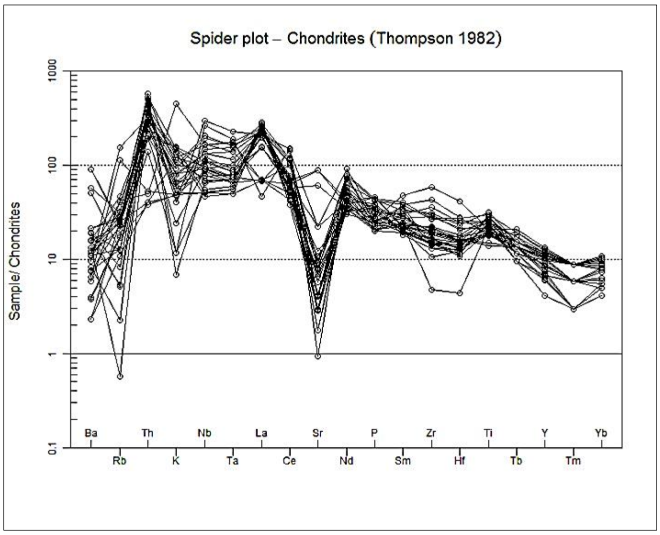

Figure 5. Primordial mantle-normalized trace element diagrams showing the compositions of stady area alkali basalt.
Source: Thompson (1982).

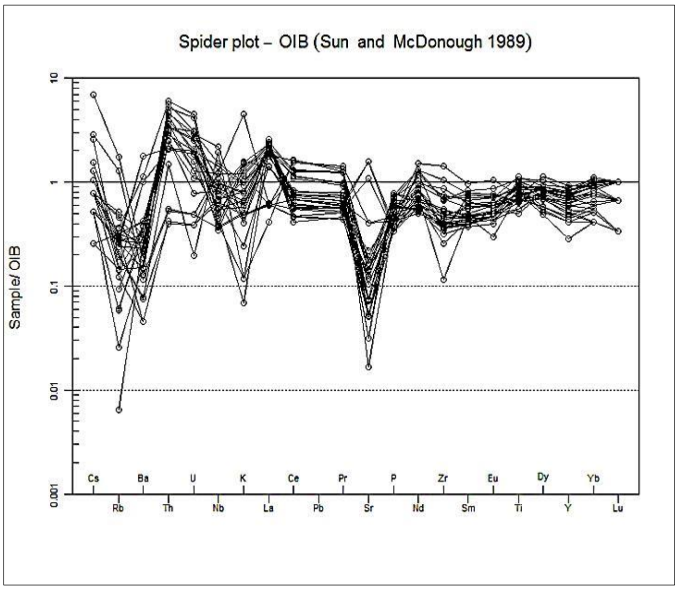

Figure 6. Primitive mantle-normalized trace element diagrams showing the compositions of stady area alkali basalt.
Source: Sun et McDonough (1989)

Also, in the normalized REE diagram, (Boynton, 1984) shows a left - to-right compatibility (severe slope LREE to HREE), which is a negative anomaly in the elements Eu و YbوNd, and a mild negative anomaly in Sm and a slight anomaly in Ce,Tm ،Tm. Due to changes in LREE / HREE and MREE / HREE and LREE / MREE gems studied, it can be concluded that the parent magma originated from Lerzolite garnet sources (Figure 7) (ANSARI,2011).

Given that the elements Ti and P are among the high field strength elements (HFSE) showing no movement during secondary processes, the observed Ti and P anomalies can be interpreted through petrological arguments. The negative Nb anomaly represents the role of magmatic contamination by the continental crust during evolution of the regional rocks.

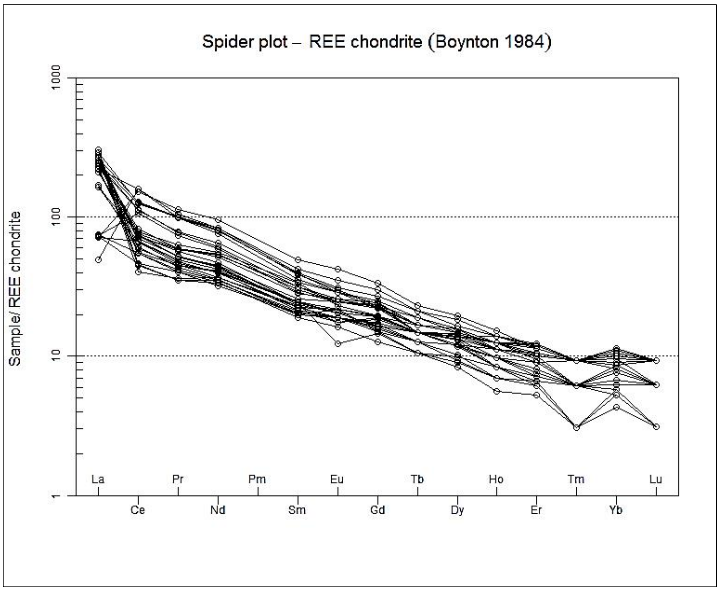

Figure 7. Chondrite-normalized REE diagrams for stady area alkali basalt.
Source: (Boynton ,1984).

TECTONIC SETTING

Meschede (1986) showed that within-plate alkaline basalt and E-MORB could be identified without ambiguity on the triangular plot of Zr–Nb–Y(Figure 8a), which is also confirmed by Rollinson (1993); Dicheng Zhu *et al.* (2007). Generally, basaltic lavas in a continental rift setting is associated with a mantle plume, the asthenosphere, the lithospheric mantle and continental crust (Sun and McDonough, 1989).

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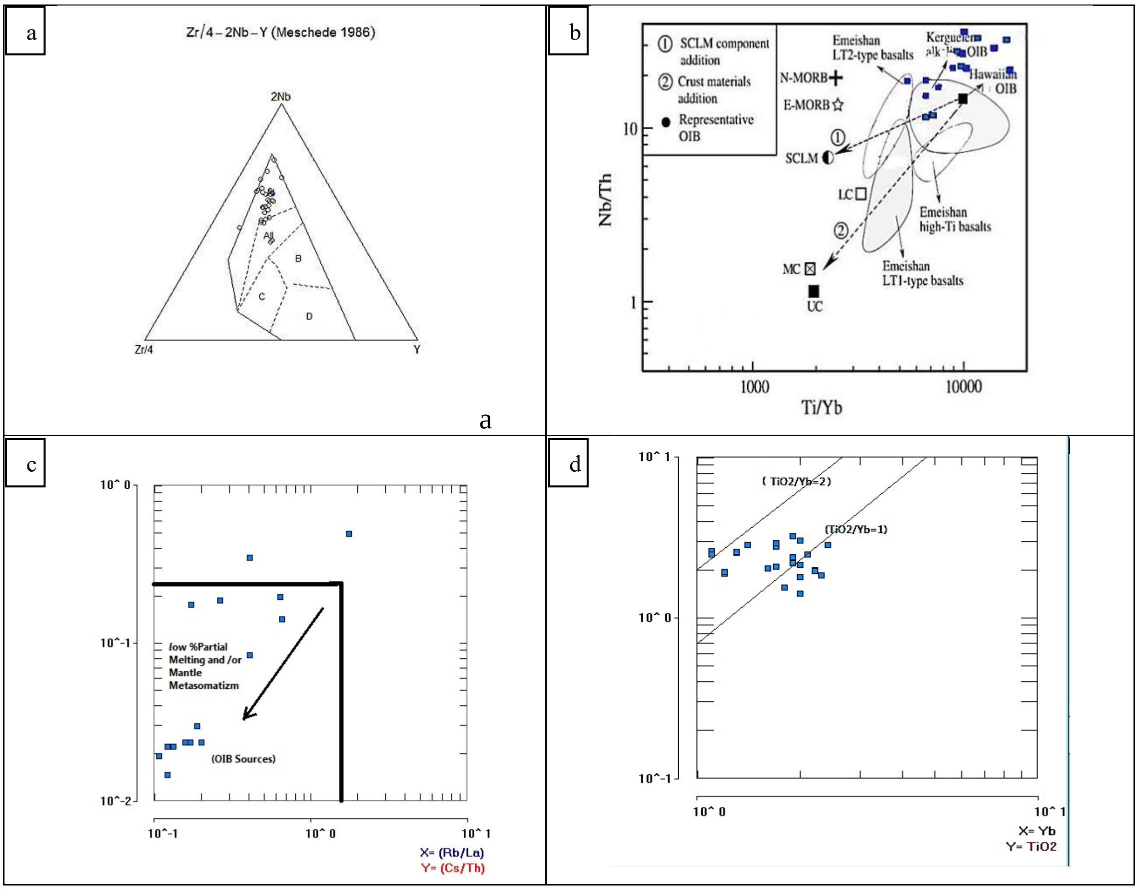


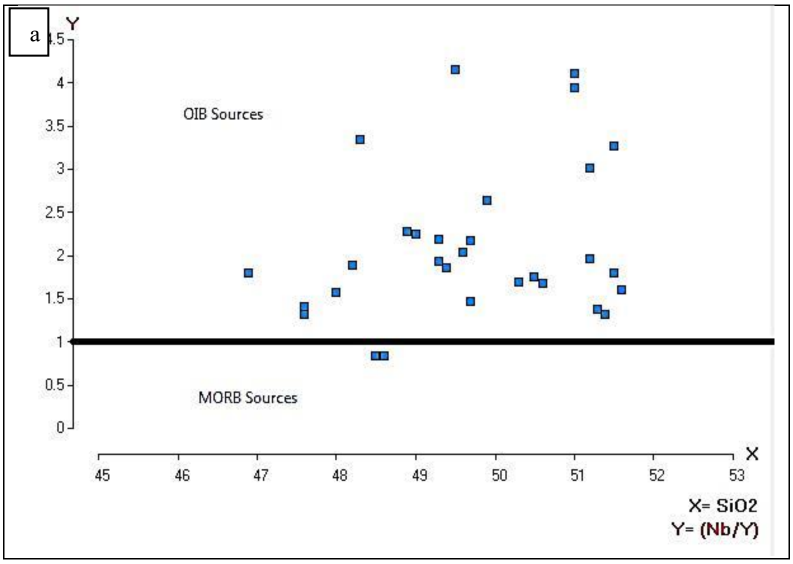
Figure 8. (*a*): Nb–Zr–Y discrimination diagram (Meschede, 1986) for the alkali basalts. The fields are defined as follows: AI, within-plate alkali basalts; AII, within-plate alkali basalts and within-plate tholeiites; B, E-type MORB; C, within-plate tholeiites and volcanic-arc basalts; D, N-type MORB and volcanic-arc basalts.(*b*): (Minster *et al*. (1978) and Allegre, 1978). (*c*) and (*d*) diagram (Parkinson & Pearce, 1993).

The Nb/Th-Ti/Yb diagram was presented to separate and determine the subcontinental mantle lithosphere, crustal contamination, and asthenospheric magma. According to the Nb/Th and Ti/Yb ratios, the majority of samples are consistent with the range of OIB sources including Hawaiian OIB related to asthenosphere plume and rising (Figure 8b).

Also, in the Rb/La-Cs/Th diagram, all samples in the area belong to magatic rocks associated with thesile regions or metasomatized mantles and do not show any relation to the subduction regions (Figure 8c).Also that high numbers of Tio2 against low values of Yb indicate a lorzolite garnet source. In the recks of the study area, changes in th, v, and Nb have also been performed in the same way as tio2. Therefore, this distinction exists between tensile regions and subduction regions and indicates the early magmas of volcanic rocks in the case study area from a source of garnt lorzolite in relation to tensile environments (PEARCE and PARKINSON, 1993) (Figure 8d).

In Sio2 - Nb/Y diagram , most of the samples are located in the OIB environment where changes in the elements HFSE‹LILE and the positive anomalies of Nb can be considered as the result of different degrees of melting of the stonospheric mantle in the rituals and intercontinental traction ,on the other hand ,parts of the stretching areas also have a negative anomaly of Nb associated with the melting of a lithospheric mantel in the rituals and intercontinental traction (HOFMANN, 1986; VERMA, 2006) (Figure 9a).

The element Y can reveal the slightest variation in the crystallization and the melting element. Using the Nb/Y-Zr/Y ratio, most of the samples are loafed within the OIB range and propose similar saurce and processes to each other for the magma of the rockes of the region. Also hoted that the position of the keratonic rocks in the above diagramis in the OIB range, except that there is a depletion in the amount of Zr and Ti (MACDONALD *et al.*, 2001)(Figure 9b).



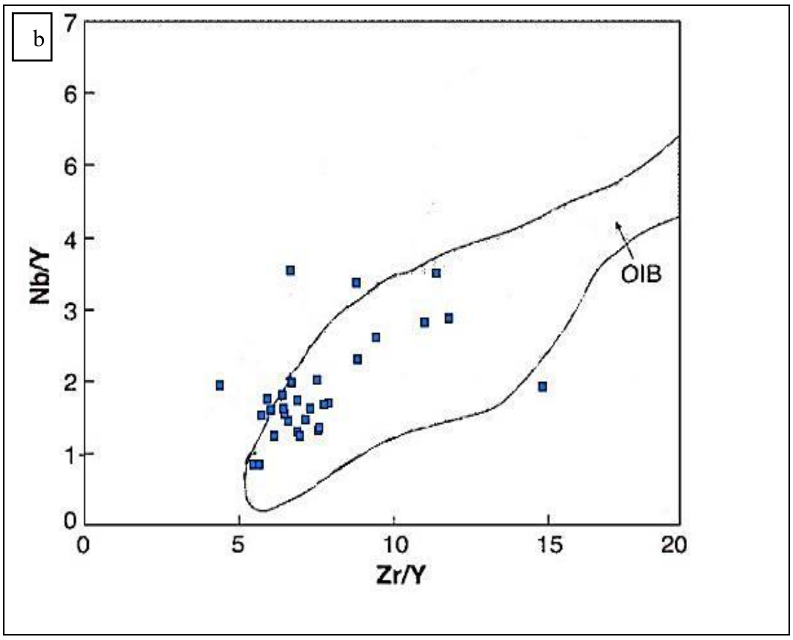
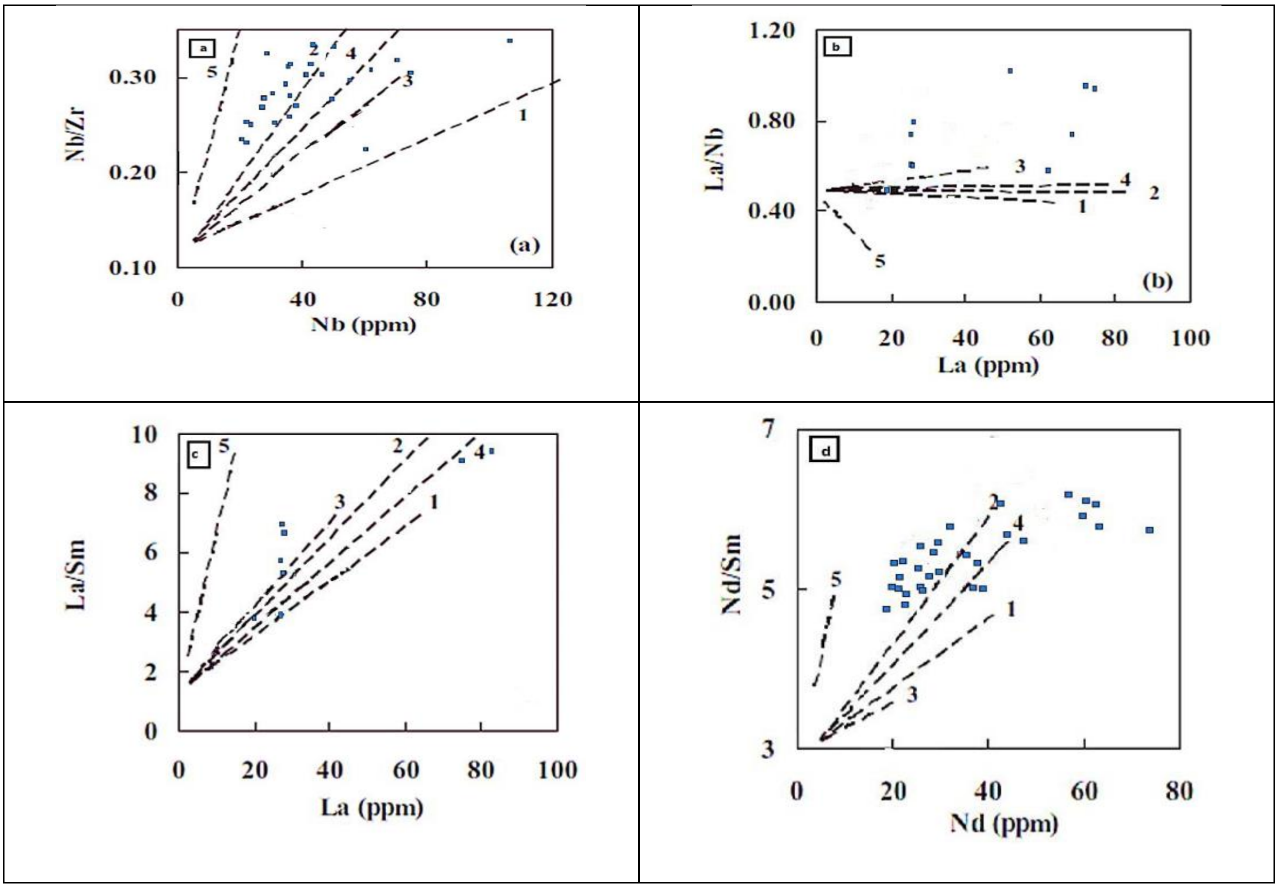


Figure 10. (*a*): Sio2-Nb/Y discrimination diagram the behavior and sources of partenal magma of volcanic rocks in the study area (Verma, 2006); (*b*) Nb/Y-Zr/Y discrimination diagram the behavior and sources of partenal magma of volcanic rocks in the study area. (Macdonald et al. 2001).

The ratios Th/ Zr - Hf/Zr were also used to determine the tectonomagmatic environments and chemical classification of the parent magma of the volcanic rocks of the study area (Sun Shuqing *et al.*, 2003) and major samples in the continental basaltic region associated with tensile and sedimentation environments Primary parifs (IV2) of the developed rocks of the study area are also located in the tectonic environments associated with the IV3 collision zones or the intracorporeal basalt (IV2). Due to the compatibility of Zr with Nb and the high Nb / Zr ratio of the studied rocks, the relationship between this ratio and the high or low melting point is suggested. These magmas are the result of mildew and melting of minerals such as amphibole, phlogopite and clinopyroxene (Ansari, 2013).

Also, changes in Tb/Yb-La/Yb (MREE/ HREE Versus LREE/HREE) have a linear trend and show different types of melting and heterogeneous sources of magma (HOFMANN & FEIGENSON, 1983).

In general, determination of the sources and different degrees of melting due to the linear array of element is difficult and mineralogical composition cannot be provided for the source magma of the study area. In Nb/Zr - Nb diagram, the samples of the studied rocks have a general trend paralle to the curve 2 and have a dispersion between lines 1, 2, 3 and 4 , and respectively have been located between the compounds of spinel Lerzolite, Garnet lerzolite, Amphibole lerzolite, and phlogopite lerzolite and are not only parallel to the process of one of the resources. On the other hand, in the La/Nb-La diagram, enriched samples have the same trend as amphibole lherzolite (Line 3) and phlogopite lorzolite (Line 4), and exhibit a stepwise of step- step slope in orease. Thus, the La/sm-La diagram also confirms the above pants and shows that only a mineralogy source can hot preduce the mdten parent of the rock study aver, and the source's heterogeneity is Diagram of Nb/Y-Zr/Y changes in ratios to identify the behavior and sources of magma production of Volcanic rocks in the study area (SHAW *et al.*, 2003) (Figure 11).



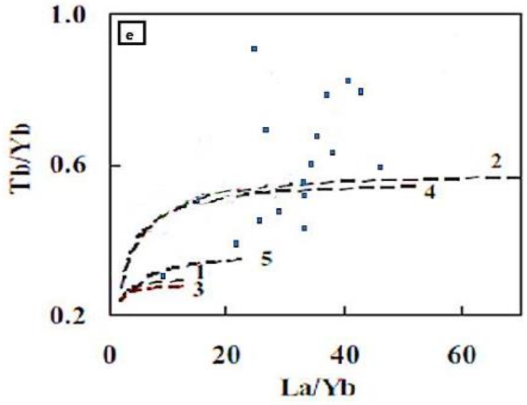
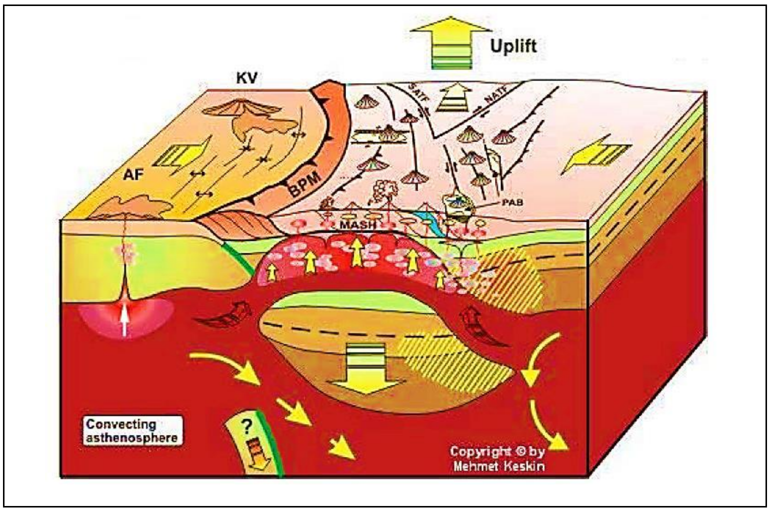


Figure 11. The diagram of the ratio of incompatible elements to their enrichment in vocamic rocks of the melting line curves between 0/1 to 25% hon modal – batch partial melting for various mineralogy sources are as follows: (1):spinel lherzolite (ol:opx:cpx:sp ratios of 60:20:15:5 and _15:50:50:15 in the rock and in the melt, respectively); (2):garnet lherzolite (ol:opx:cpx:gt ratios of 60:20:10:10 and 0:30:35:35 for the rock and melt, respectively); (3):amphibole lherzolite (ol:opx:cpx:am ratios of 55:20:5:20 and _15:35:15:65, respectively); (4):phlogopite–garnet lherzolite (ol:opx:cpx:gt:phl 65:15:10:7:3 and 5:15:60:10:10, respectively); (5):amphibole–garnet clinopyroxenite (cpx:sp:gt:am 75:10:10:5 and 25:20:30:25, respectively) Source: Shaw et al. (2003).

The depletion of the incompatible element K indicates the presence of a potassium-containing resisting remnant phase during melting of a mantle source. Given the severe Rb depletion and enrichment of the rocks by HFSE, an amphibolic mantle seems to be the source of the primary magma. Phlogopite seems unlikely to be the K phase in this mantle source. The negative Ce anomaly, positive Nb anomaly and an OIB-source-like Pb/Ce ratio and diversity of the Ce/Pb ratio, contamination of the mantle sources by the detached dense lithosphere and sinking in the mantle highlight the role of mantle and continental lithosphere in the contamination of magmatic sources of the regional volcanic rocks. Considering the lack of crustal contamination of the parental magma of the rocks, delamination and detachment of the lithosphere and its sinking in the mantle (due to density difference) and the transfer of the dense lithosphere to higher depths (lower mantle) can be attributed to the contamination of the magmatic source (or sources) by the lithosphere for the primary magma of volcanic rocks in the study area.

The HFSE, LILE and REE ratios were evaluated to understand the behavior and sources of the parental magma production in the Cretaceous volcanic rocks. The results indicate a rich origin similar to the OIB oceanic basalts. The MREE, LREE and HREE enrichment such as the La/Yb, Tb/Yb ratios shows the relationship of primary magmas with enriched OIB sources and various melting degrees of a garnet peridotite to a garnet-free peridotite source representing magma formation at high pressures and depths. The lead (Pb) and uranium (U) levels in the mantle sources may change due to contamination of the HIMU sources by delamination of the subcontinental mantle lithosphere leading to formation of enriched EMI and EMII sources. Therefore, delamination of the lithosphere and its mixing with the HIMU sources cause a change in the nature of the lithospheric sources beneath the Central Alborz. Since the Alborz range is similar to the East Anatolian Zone, both belong to the Alpine-Himalayan Orogenic Belt (KESKIN, 2005), a hybrid (composite) model of subducted plates and lithosphere delamination was proposed for collision zones such as the Alpine-Himalayan Zone (Figure 12).



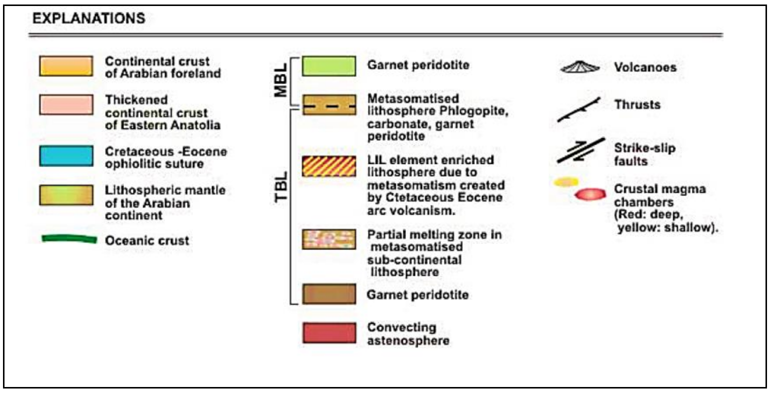


Figure 12. A hybrid (composite) model of subducted plates and lithosphere delamination for the formation of the Alborz range.
Source: Keskin (2005).

CONCLUSIONS

This study present new chemical data significant to our understanding of mid cretaceous intraplate magmatism related to sub-continental lithospheric mantle delamination, asthenospheric mantle upwelling, graben structure, deep fault and local rift system in study area volcanic suite, central Alborz mountain ranges, North of Iran.

The study area alkali basalts have domain rock type between basalt to trachy andesite and andesite.

The major and trace element composition of the study area alkali basalts is controlled by fractional crystallization of olivine, plagioclase, Fe-Ti oxide ± clinopyroxene.

The major element variation and the REEs variability ratio of study area alkali basalts, could be produced by

decompressing of a garnet lherzolite mantle source and vary degrees of partial melting.

The study area alkali basalts were derived from an OIB-type mantle source with discernable sub-continental lithospheric mantle sources and are generated from heterogeneous source with prominent geochemical heterogeneities.

Investigating the relative behavior of the elements of LILE, HFSE and REE in order to know the behavior and sources of magma production of the Cretaceous volcanic rocks of the studied area have a rich source similar to OIB oceanic basalts, and therefore the role of upper, middle, lower and The sub-continental lithosphere estimates the initial magma to be negligible.

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