Geochemical Constrain on the Early Cretaceous, OIB-type Alkaline Volcanic Rocks in Kojor Volcanic Field, Central Alborz Mountain, North of Iran.

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Abstract: The Kojor volcanic field (KVF), North of Iran contains a number of intra-continental alkaline volcanic range situated on central Alborz Mountains, formed along the localized extensional basins developed in relation with the lithospheric thinning and Cretaceous compressional processes. The volcanic suite comprises the extracted melt products of adiabatic decompression melting of the mantle that are represented by small-volume intra-continental plate volcanic rocks of alkaline basalts and their evaluated Rocks with compositions representative of mantle-derived, primary (or near-primary) melts. Trace element patterns with significant enrichment in LILE, HFSE and REEs, relative to Primordial Mantle. Trace element variations of individual basaltic rocks are characterized by an increase in incompatible elements and MgO, with decreasing SiO2, as melt production proceeds. They are mainly alkaline basalt. Most of these rocks display overlapping primitive Mg-numbers, Cr and Ni contents, steep chondrite-normalized rare earth element patterns (La/Yb CN = 6.46–19.26) and an overall enrichment in incompatible elements. The existence of distinct primary magmas is also indicated by heterogeneity in highly incompatible element ratios (e.g. Zr/Nb, La/Nb). Trace element modelling indicates that the magmas were generated by comparably variable degrees of partial melting of different garnet lherzolite and a heterogeneous asthenospheric mantle source.

Key words: Alborz; Iran; garnet lherzolite; partial melting.

INTRODUCTION

Continental volcanic rocks can provide important information about paleo-geodynamic settings and the processes controlling the geochemical evolution of the sub-continental mantle. However, systematic studies of igneous rocks and the chemical composition of the mantle underlying the continental plate are few in number. Alkaline basalt occurs in a variety of geologic and tectonic settings and their detailed study in space and time helps in various ways to understand several geological events. Thought to be an integral part of continental rifting and / or local extensional regime occur in continental fragments. They also serve as major conduits for magma transfer from mantle to the upper crust and constitute a common expression of crustal extension. Another important point is that most of these rocks have their origin related in some way to the uprise of hot mantle plumes that ultimately may lead to rifting and, ultimately, continental break-up. The mantel source of alkaline basalt is very common and the study of these rocks is an important tool in understanding the evolution of the sub-continental lithosphere and asthenospheric. The magmatic rocks of Alborz mountain range also have different petrological nature. These cretaceous basaltic rocks are well exposed around central part of Alborz mountain range. This rock is known as Javherdasht and Javaherdeh cretaceous volcanic field, (GSI, 1997; Haghnazar et al 2009) Amlash cretaceous volcanic field and Central Alborz. These rocks consist of a variety of alkaline and basaltic rocks. Most previous workers (GSI, 1997; Haghnazar et al 2009) have given their attention to examine the alkaline rocks only and no petrological and geochemical work is available on these basic rocks. First hand petrological and geochemical information on volcanic rocks of Kojor volcanic field and a suggestion on their possible origin have been resented in the present paper. The detailed petrological and geochemical studies of these rocks are important because most of these follow the direction of major structural features, particularly the deep faults present in the region. Space and time correlation of these rocks with other volcanic rocks suite derived from the sub Alborz mantle plume will help in understanding the continental break-up during the Cretaceous time.
**Geological setting:**

The Alborz mountain chain extends for several hundreds of kilometres between the Caspian Sea and the Iranian Plateau (Fig. 1b). The belt is the result of different tectonic events: from the Late Triassic Cimmerian orogeny, resulting from the collision of the Iranian block with Eurasia, to the present day stage of intracontinental deformation related to the convergence between the Arabian and Eurasian plates. Important large-scale features of the belt consist in the lack of an axial metamorphic zone and in the absence of deep crustal roots (crustal thickness is 35 km, according to (Tatar et al., 2002), which is apparently in contrast with the present day elevation of the belt (several summits over 4000 m) which was achieved since Late Miocene (Axen et al., 2001). The oldest compressional event recorded in the area is the Cimmerian orogeny, which affected the Eurasian margin from Turkey to Thailand. It was chiefly caused by the early Mesozoic collision of several microplates detached from Gondwana. According to palaeogeographic reconstructions (Stocklin, 1974; Stampfli et al., 1991; Saidi et al., 1997; Besse et al., 1998; Gaetani et al., 2000; Stampfli and Borel, 2002), the Iranian microplate was the first block to collide with Eurasia during Middle-Late Triassic forming the Eo-Cimmerian orogeny. This event is recorded by a low-angle regional angular unconformity (Stocklin, 1974; Jenny and Stampfli, 1978) along the northern margin of the Iranian plate, sealed by the Upper Triassic-Jurassic Shemshak Formation (Assereto, 1966a; Seyed-Emami, 2003). 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 (Ruttnner, 1993). Tentatively traces the Paleotethys suture westward across the Gorgan region to the Talesh mountains (western Alborz), where metamorphic nappes (Clark et al., 1975; GSI, 1997) are unconformably covered by the Shemshak Formation. The record of the Eo-Cimmerian orogeny is less evident in the central part of the Alborz. The Upper Triassic succession is almost continuous (Ghasemi-Nejad et al., 2004) 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.

**Geological Setting of the Central Alborz:**

The stratigraphic succession of the central Alborz (Assereto, 1966b) spans the whole Phanerozoic, Precambrian and Cambrian succession is represented by coastal sandstones and dolostones, with continental deposits in the Early Cambrian. Ordovician and Silurian are poorly represented, whereas the Devonian-Middle Triassic succession and consists of predominately shallow marine carbonates intercalated with basaltic lava flows, evolving to a widespread carbonate platform sedimentation in the Triassic (Elka Formation). The latest Precambrian to Middle Triassic succession is unconformably covered by the Shemshak Formation, up to 4000 m thick, deposited after collision of the Iran microplate to the Eurasian margin. The age of the base of the Shemshak Formation is diachronous, being Late Triassic in the central Alborz and Early to Middle Jurassic to the north toward the Caspian Sea (Clark et al., 1975; Seyed-Emami, 2003; Ghasemi-Nejad et al., 2004; Fursich et al., 2005). This formation consists of continental sandstones, shale and coal passing upward to shallow marine deposits blanketing the Eo-Cimmerian orogen and its foreland. The Eo-Cimmerian unconformity is particularly evident in the Shemshak area, where the basal beds of the formation lie directly on the Permo-Carboniferous units. The shallow water Marine Middle Jurassic–Early Cretaceous carbonates and clastics were followed by early Cretaceous carbonates, basaltic and andesitic volcanic across large parts of the Alborz such as Chaloos formation and Tizkuh formation, which is irregularly preserved and locally folded (Guest et al., 2007). The Kojor early cretaceous volcanic field is considered a member of Chaloos formation and is located in central part of Alborz mountain ranges. Kojor volcanic alkali basalt is a large composite of the above mentioned volcanic suite which is consist of mainly Olivine basalt-Andesite Basalt, Dolerite, and subordinate pyroclastic materials (GSI, 1997).

**Research Methodology:**

Sixteen samples were collected from volcanic outcrops in the Kojor area, representing the entire early cretaceous sequence of the central Alborz range. These samples were prepared for analysis major and trace elements and determined by inductively coupled plasma atomic mass spectrometry (ICP-AMS) at ACME lab, Vancouver, Canada, by VAN10005683.1 and VAN10006800 file number with 4A, 1F-MS and 1T-MS full suite packages.

**Results:**

**Petrography:**

The petrography of the Kojor Volcanic rocks Field (KVF) (fig. 1a), along with the geology and the contemporaneous volcanic rocks in vary part of central Alborz mountain has been previously described by (GSI, 1997; Haghnavaz et al 2009).

Most of samples have composition range between alkaline olivin Basalt – Trachyandesite Basalt and some samples are hypabyssal doleritic rocks.
An overall consideration of the investigated basic volcanic rocks indicates that primary mineralogy in the alkali basalts is composed of olivine + plagioclase + clinopyroxene (pinkish Ti-augite) ± brown amphibole (xenocryst) + opaque oxides (e.g. Titanomagnetite), whereas the secondary mineral phases are represented by serpentine + epidote + chlorite + calcite.

**Major and trace element chemistry:**

The lavas from both Kojor volcanic field (KVF) are a strongly alkaline series of volcanic rocks, with almost all samples plotting in the alkali basalt and trachybasalt fields on a total alkalis (K2O+Na2O) vs. silica (SiO2) classification diagram of Le Bas et al. (1986) (Fig. 2). The alkaline rocks are mainly, sodic (Na2O/K2O=2.9–5.67) and have high Mg# [cation proportion]

**Fig. 1:** (a) Simplified geological map of the Kojor area, from GSI.(1997)and our own observations.(b) Tectonic map of the Central Alborz, modified from Allen et al. (2003).(Zanchi et al., 2006).

Mean Mg/ (Mg+Fetotal)](29.7–64.7) and high MgO (4.4–11.4 wt.%) over a range of SiO2 content from 44.7 to 53.3 wt.%. The analyzed samples have moderate Ca (7.4–11.03 wt.% CaO) and high Al (13.8–17.5 wt.% Al2O3) contents and their Cr and Ni concentrations range variably from 41 to 170 ppm and from 97 to 293 ppm, respectively. On the Zr/TiO2 vs. Nb/Y diagram of Winchester and Floyd (1977), the KVF rocks fall in alkaline basalt – basanite field (Fig. 3). Although, rock types and whole-rock chemical compositions indicate that they are closer to primary melt compositions the alkaline rocks have almost straight and relative to chondrite normalized (CN indicates chondrite normalized) REE pattern with near-constant concentration ratios. The absolute REE abundances increasing with decrease SiO2 content. (Fig. 8) All samples have REEs enriched patterns on chondrite-normalized REE plots. The KVF lavas also have all the classic enrichments in LILE, HFSE and REEs (e.g., relative to the average Primordial mantle normalizing values) that characterize basalts from intraplate continental and oceanic island basalt settings (Fig. 4). These rocks also display prominent
negative Rb, Hf and slightly k, Ce, U anomalies and shown Nb, Pb and Zr positive anomalies. Primitive mantle normalized incompatible trace element patterns (Fig. 5) are similar to those of ocean island basalts (OIB) (Fig. 6), with strong enrichment in most highly incompatible elements. This enrichment is stronger in the alkali basalts than in the trachyandesites basalts. Alkali olivine basalts to trachyandesites basalts. In addition, this rocks show negative anomalies of Rb, K and U and also positive Th anomalies. (Fig. 5)

### 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, which is also confirmed by Rollinson, 1993; Dachv Zhut et al., 2007.

### Table 1: Major (wt %) and trace element (ppm) concentration of chemical composition of the investigated from KVF alkali basalt.

<table>
<thead>
<tr>
<th>Sample</th>
<th>ABS6</th>
<th>ABS5</th>
<th>ABS4</th>
<th>ABS3</th>
<th>ABS2</th>
<th>ABS1</th>
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<tr>
<td>SiO₂</td>
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<td>94.74</td>
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<td>94.43</td>
<td>94.74</td>
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<tr>
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<td>22.07</td>
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<td>0.17</td>
<td>0.17</td>
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<tr>
<td>Cr</td>
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<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<td>0.11</td>
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<tr>
<td>MnO</td>
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<td>0.01</td>
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<tr>
<td>MgO</td>
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<td>18.98</td>
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<td>18.98</td>
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<td>11.39</td>
<td>11.44</td>
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<td>11.39</td>
</tr>
<tr>
<td>MgO₂</td>
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<td>0.18</td>
<td>0.18</td>
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<tr>
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<tr>
<td>Mn₂O₇</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>Mn₂O₈</td>
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The Zr–Nb–Y diagrams (Fig. 9a) illustrate that the KVF basalts are characteristic of within-plate alkaline basalts, which to a large extent resemble the representative OIB (Sun and McDonough, 1989).

Generally, basaltic lavas in a continental rift setting is associated with a mantle plume, the asthenosphere, the lithospheric mantle and continental crust. Increasing Zr/Y ratios in contrast Zr variation of KVF basalts are comparable to increase in Zr concentration (Fig. 9b). The Zr/Y ratios, reflected relatively high values owing to higher incompatibility of Zr compared to Y in mantle phases (e.g. Pearce and Norry 1979; Pearce 1980; Nicholson and Latin 1992; Kaan et al., 2009). Therefore, the KVF rocks could have been generated by varying degrees of melting. It must also be noted that amphibole fractionation may have accounted for a small increase in Zr/Y ratios (Kaan et al., 2009) high Zr/Y values of KVF samples (Zr/Y = 6.5–11.4) may suggested their derivation from enriched mantle sources or possible contribution of a mantle plume (OIB, Zr/Y
= 9.66, E-MORB = 3.32; Sun and McDonough, (1989) Or derivation from mantle metasomatized and/or by vary degrees of low fusion. The Zr/Nb values (Zr/Nb = 2.11–5) also support this suggestion. On the other hand, considerable high Zr/Nb values (Zr/Nb = 28.9–43.4) together with relatively low Zr/Y ratios may provide the contribution of depleted mantle during their generation (MORB, Zr/Y = 2.64, Zr/Nb = 31.8, Sun and McDonough (1989). lowest Y/Nb values (Y/Nb = 0.23–0.74) may be related to the involvement of enriched mantle sources and considered the garnet is a present phase in the source. The existence of residual garnet results in depletion of HREE relative to LREE because of the strong retention of HREE in garnet (e.g. Wilson 1989; Spath et al. 1996).

Fig. 2: Classification of the KVF alkali basalt samples in the TAS diagram after Le Bas et al. (1986) with alkaline’sub-alkaline magma series.

Fig. 3: Nb/Y–Zr/TiO2 diagram of Winchester and Floyd (1977) showing the alkaline basalt affinity of the KVF volcanic rocks.
Fig. 4: Primordial mantle-normalized trace element diagrams showing the compositions of KVF alkali basalt. Primitive mantle normalizing composition is from Sun & McDonough (1989).

Fig. 5: Primitive mantle-normalized trace element diagrams showing the compositions of KVF alkali basalt. Primitive mantle normalizing composition is from Sun & McDonough (1989).

Fig. 6: OIB normalized trace element diagrams showing the compositions of KVF alkali basalt. Primitive mantle normalizing composition is from Sun & McDonough (1989).
Fig. 7: N-MORB normalized multi element patterns diagrams for KVF alkali basalt. Normalizing values are from (Sun and McDonough 1989).

Fig. 8: Chondrite-normalized REE diagrams for KVF alkali basalt. Normalizing values are from (Boynton 1984).

Fig. 9: (a) Nb–Zr–Y discrimination diagram (Meschede, 1986) for the KVF 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) Tectonomagmatic discrimination plots of the studied sample KVF alkali basalts after Pearce and Norry (1979).
As indicated by high partition coefficients of those elements (e.g. Green et al. 1989; Jenner et al. 1994). The alkaline basalts display considerable depletion HREE compared to LREE ([La/Yb]CN suggesting the presence of garnet as a residual phase in the source of these basalts. It must also be noted that [Tb/Yb]CN values of KVF basalts ([Tb/Yb]CN = 1.41–1.86, respectively) are somewhat in agreement with those of alkaline basalts from Hawaii ([Tb/Yb]CN = 1.89–2.45), which are also thought to be derived from a garnet-bearing source. However high Dy/Yb ratios displayed by alkaline basalts (Dy/Yb = 1.3–1.79) with respect to that of chondrite (Dy/Yb = 1.49; Sun and McDonough 1989), on the other hand, may suggest a garnet-bearing lherzolite source for the derivation of these alkaline basalts. Taking the geochemical discrimination diagrams into account it is concluded that the KVF basalts were formed in a continental extensional setting, although the volcanic rocks have similar geochemical features to OIB.

Petrogenesis of Alkaline Rocks and Mantle Process:

The foregoing description suggests that the KVF alkali basalts may have been derived from mantle source materials resembling those of many oceanic island basalts. This will be further corroborated in the following discussion. Nb, Th and La are immobile elements and seawater alteration would not change the Nb/Th and La/Nb ratios (Dicheng Zhu et al., 2007). These ratios are also not susceptible to magma processes because they have similar partition coefficient (Li., 1993; Dicheng Zhu et al., 2007). The island arc basalts, MORB and OIB can be distinguished well by La/Nb–La diagram (Fig. 10). Obviously, the KVF alkali basalts all plots within the OIB field is shown in the following diagram (Fig. 10).}

Fig. 10: Trace element discrimination diagrams for the tectonic setting of Cretaceous basaltic rocks in KVF, North of Iran, La vs. La/Nb diagram after (Li,1993) showing characteristics of an OIB-type source. The fields are defined as follows: IAB, Island-arc basalts; MORB, mid-ocean ridge.

OIB Basalts; oceanic island basalts:

On the other hand, Shaw et al, 2003; Weinstein et al, 2006 argued that alkali basaltic magmas are formed by relatively shallow melting of lithospheric mantle. A lithospheric mantle source seems also not to be necessary for the KVF alkali basalts (Fig. 11), although, OIB-type characteristics exert a strong control on the trace element systematic of these basalts. The (Yb) CN-(La/Yb) CN diagram (Fig.11) illustrates the approximate melt compositions of the KVF alkali basalts, which fall between the garnet lherzolite field non-modal fractional melting curves, suggesting that the magmas were formed by the melting of garnet lherzolite and we find no evidence for spinel lherzolite melting. The notable fractionation between the LREE and HREE ((La/Yb)CN = 6.46–19.26) and the high (Yb)CN(7.65–11.48) of the KVF alkali basalts correspond a low degree between(5-12%) partial melting of garnet lherzolite. Trace element ratios such as Nb/Th and Ti/Yb are helpful in distinguishing crustal contamination from interaction with sub-continental lithospheric mantle, because these ratios are very sensitive to the crustal contamination of mantle-derived magmas (Li et al., 2002; Dicheng Zhu et al., 2007).
In the Ti/Yb vs Nb/Th plot (Fig. 12), most KVF alkali basalts show relatively uniform Ti/Yb and Nb/Th ratios, close to those of the representative alkaline OIB (Sun and McDonough, 1989), and shown lesser-contaminated basalts plot with sub-continental lithospheric mantle and/or the lower crust. It is well known that there is no sub-continental lithospheric mantle beneath Hawaii, thus the Ti/Yb vs Nb/Th plots seem imply that sub-continental lithospheric mantle and/or lower crust components were affected to generation of the KVF alkali basalts. Most of authors (e.g., Mehdizadeh et al., 2002; Liardt et al., 2008; Taki et al., 2009) suggested magmatism in Alborz mountains related to an enrichment event must have modified the mantle source prior to the initiation of partial melting. Metasomatic agents affecting the mantle sources may have included either volatile-rich partial melts or H2O–CO2 fluids that originated from the dehydration or partial melting of subducted slabs (Menzies and Hawkesworth, 1987; Hawkesworth et al., 1990) or from plume heads (McKenzie, 1989; Tainton and McKenzie, 1994). A number of geochemical studies on Damavand dormant volcano and other basaltic rocks in central Alborz shown Nb, Ta, and Ti depletions, LILE enrichment, positive Ba and Pb anomaly as well as their similarity to the shoshonitic series lavas were regarded as a ubiquitous subduction zone signature by Mehdizadeh et al., 2002; Liardt et al., 2008; Taki et al. 2009. These authors also indicated that the enrichment event was related to subduction of both the ocean-like Caspian crust to the southwest or the Paleo-Tethyan subduction, induced by the Zagros formation, to the northeast. Recently published studies suggest, on the contrary, that the northwest extrusion of the South Caspian region was accommodated by subduction beneath the north Caspian region to the north (Axen et al., 2001; Allen et al., 2002; Allen et al., 2003; Ritz et al., 2006; Hollinsworth et al., 2008). In addition, a number of studies on the geodynamic of the Paleo-Tethys demonstrate that Paleo-Tethys oceanic crust subducted northward from Late Devonian to Late Triassic time underneath the Turan Plate. On the other hand, Jaffaian et al., 2008 and Haghnavaz et al., 2009, mentions, alkali basalt magmatism in central Alborz related to deep mantle melting and/or mantle plume accompanied by crustal contamination in local extensional regime and/or deep faults system. Alborz orogenic belt formed by continental-continental collision between the central Iranian block and the Eurasian plate (Vernant et al., 2004). Therefore, Alborz region, exhibiting plateau morphology with an elevation 3000-5000 m above sea level. Geophysical studies have revealed that a mantle lithosphere is almost completely absent beneath the Alborz mountains (e.g., Sodoudi et al., 2009; Mirnejad et al., 2010). Bouguer anomaly modeling estimated crustal thickness of 35–40 km under the central Alborz and stimulated the idea of root deficiency (Dehghani and Makris, 1984). A relatively thicker crust (45–46 km) was shown for the same region based on surface wave analysis of a few events (Asudeh, 1982; Doloei and Roberts, 2003). The relatively thin crust for a 100 km wide, 3–5 km high mountain range has also been interpreted to be indicating lack of compensation by a lithospheric root (Guest et al., 2007).

Inadequate crustal root and the relatively thin lithosphere beneath the Alborz may imply that asthenospheric mantle is supporting the high elevation (Sodoudi et al., 2009). Absence of a crustal root in the Alborz may be due to lower crustal flow and sub-continental delamination as speculated by Allen et al., 2003; Mirnejad et al., 2010).
Fig. 12: Plot of Nb/Th vs. Ti/Yb for the KVF basalts, from Zhu et al. (2005). Data for Hawaiian OIB are from Feigenson et al. (1996), Emeishan LT1, LT2-type and high-Ti basalts data are from Xiao et al. (2004). Note that all the KVF alkali basalt samples plot between Hawaiian OIB and sub-continental lithospheric mantle/lower crust, the lesser-contaminated samples plot toward the sub-continental lithospheric mantle and/or lower crust subcontinental lithospheric mantle (SCLM) values are from McDonough (1990); upper crust (UC), middle crust (MC) and lower crust (LC) values are from Rudnick and Gao, 2003.

Deep mantle melting and the delamination of sub-continent lithosphere in collision zone are explained by Lustrino (Lustrino, 2005). This model presented here is based on the role of lower crust and lithospheric mantle recycling by delamination and detachment. This process can explain at least some geochemical peculiarities of basaltic rocks found in large igneous provinces, as well as in small volume igneous activities, as well as in mid-ocean ridge basalts (Lustrino, 2005). Metamorphic reactions occurring in the lower continental crust as a consequence of continent–continent collision lead to a density increase (up to 3.8 g/cm3) with the appearance of garnet in the metamorphic assemblage (basalt amphibolites garnet clinopyroxenite/eclogite). This process leads to gravitational instability of the overthickened lithospheric keel (lower crust+ lithospheric mantle). This may detach from the uppermost lithosphere and sink into the upper mantle. Accordingly, metasomatic reactions between SiO2-rich lower crust partial melts and the uprising asthenospheric mantle (replacing the volume formerly occupied by the sunken lithospheric mantle and the lower crust) lead to formation of orthopyroxene-rich layers with strong crustal signatures.

In summary, major and trace element data suggest that the KVF alkali basalts may have been derived from an OIB-type mantle source without major affecting to contribution subcontinental lithospheric mantle and/or lower crust. This study indicated that a huge piece of subcontinental lithospheric mantle (SCLM) and/or lower crust of beneath Alborz mountain ranges has been delaminated and detached from the upper crust in the past, which caused the thinning of lithosphere by graben structure and continental rifting. In general, isostatic relaxation follows regional shortening and thrust/nappe formation during continent-continent collision. The volume opened by the removal SCLM would be replaced by a new hot asthenospheric mantle plume. Melt and/or fluid derivation from lower crust or SCLM could be hydrated and metasomatized mantle plume (Lustrino, 2005; Keskin, 2005). Therefore, adiabatic ascent and hydration of asthenospheric mantle cause melt derivation from asthenospheric mantle by decompressing of mantle. The variable degrees of partial melting (Fig. 12b) observed in the source of the KVF lavas are probably due to the pulsing influx of mantle plume material (Krientz et al, 2007).

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

1. The KVF alkali basalts have domain rock type between olivine basalt to olivine trachyte and hypersuysal olivine dolerite.
2. The major and trace element composition of the KVF alkali basalts is controlled by fractional crystallization of olivine, plagioclase, Fe-Ti oxide ± clinopyroxene.
3. The major element variation and the REE variability ratio of KVF alkali basalts, could be produced by decompressing of a garnet lherzolite mantle source and vary degrees of partial melting.
4. The KVF 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.

REFERENCES


