Geochemical evidence for deep mantle melting and lithospheric delamination as the origin of the inland Damavand volcanic rocks of northern Iran

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The intraplate Damavand volcanic field that overlies the Alborz Mountains in northern Iran is dominantly comprised of trachyandesite and alkaline olivine basalt. Alkaline olivine basalt is the most primitive rock type among Damavand lavas and exhibits a number of geochemical characteristics (e.g., high MgO, Ni and Cr abundances) that preclude substantial differentiation and crustal contamination. The lavas are light rare earth element enriched and have small negative Nb-Ta-Ti and positive Ba and Pb anomalies. The initial Nd and Sr isotope compositions of these lavas plot within the mantle array and cluster near bulk silicate Earth-values, while Pb isotope ratios are typical of modern upper crust. Oxygen isotope ratios range from +6.5 to +6.9‰. Although previous studies suggest that the mantle source of the Damavand volcanic rocks was metasomatized by the release of fluids during Tertiary subduction of Neo-Tethys oceanic crust under the Iranian Plate, the geochemistry of the alkaline olivine basaltss (e.g., BSE-like Sr and Nd isotopic compositions; the position of samples on Ti/V vs. Zr/Nb, Ce/Pb vs. Ce, and Th-Ta–HF diagrams) is not reconcilable with derivation of the parental magma from such a mantle source. In addition, the Mid-Ocean Ridge Basalt (MORB) normalized trace element patterns of the Damavand alkaline olivine basaltss most resemble those of Ocean Island Basalt (OIB) that implies the role of deep mantle source in their genesis. It seems that local upwelling of deep mantle materials underneath the Alborz Mountains resulted in the eruption of intraplate Damavand lavas. Compressional stress exerted on the Iranian plate following Neo-Tethys closure was the likely cause of sub-continental lithospheric delamination which led to such local mantle upwelling.

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1. 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 Iranian continental plate are few in number. The Damavand volcano, a Plio-Pleistocene volcanic center in north-central Iran, rises to an elevation of 5670 m and covers an area of approximately 800 km² (Fig. 1). The results of K/Ar, 40Ar/39Ar and (U–Th)/He dating methods suggest that Damavand volcanism has occurred frequently from the Late Pliocene to the Holocene (Davidson et al., 2004; Liolard et al., 2008).

The nature of the source region for Damavand magmatism is a matter of considerable controversy. Jung et al. (1976), Brousse and Moine-Vaziri (1982), and Aftabi and Atapour (2000) based on petrography and major element compositions, attributed Damavand volcanic activity to Cenozoic Neo-Tethys oceanic subduction under central Iran. Mehdizadeh et al. (2002) and Liolard et al. (2008) suggest that the source of the Damavand lavas is a metasomatized mantle, modified by subduction process. Davidson et al. (2004) consider that the initiation of Damavand intraplate volcanic activity was associated with local hotspot. However, the nature of mantle source enrichment as well as the mechanism of subduction beneath Damavand volcano has not yet been discussed. Our study presents major and trace element data and Sr, Nd, Pb and O isotope compositions for a number of volcanic rocks from Damavand, with the aim of addressing the nature of the mantle source and evaluating the role of convergent margin versus intraplate processes in their genesis.

2. Geology

The Alborz Mountain Range is a 600 km long and 100-km-wide east–west trending fold and thrust belt that stretches across northern Iran and south of the Caspian Sea (Fig. 1). The bedrock consists of Paleozoic–Mesozoic passive-margin sedimentary sequence with few
volcanic rocks, overlain, in the south, by Tertiary volcanics and sediments. The Alborz is seismically active as it accommodates near 25% of the whole Arabian–Eurasian convergence in Iran (Vernant et al., 2004). Recent fault movements are mainly reverse with range-parallel sinistral component (Jackson et al., 2002) although sense of the strike-slip offsets was just the opposite before ca. 5 ± 2 Ma (Axen et al., 2001).

According to Sengör et al. (1993) and Zanchi et al. (2006), the Alborz range results from different tectonic events, which occurred during two major orogenic cycles: (1) the Late Triassic (Cimmerian) demise of the Paleotethys and collision of the Iranian block with Eurasia; and (2) the post-Neo-Tethys, intraplate deformation related to the convergence of the Arabian and the Eurasian plates. The final closure of Neo-Tethys and suturing of the Afro-Arabian and Iranian plates are recorded in the Zagros orogenic belt, part of the Alpine–Himalayan orogenic belt that extends from Europe, through Iran, to western Pakistan. From SW to NE four main structural units comprise the Zagros orogenic belt: Zagros folded belt, Crush zone (High Zagros), the Sanandaj–Sirjan zone (SSZ), and the Urumieh–Dokhtar magmatic belt (UDMB) (Stöcklin, 1968; Braud and Ricou, 1971; Berberian and King, 1981; Bina et al., 1986; Alavi, 1994; Agard et al., 2005).

Damavand volcano, located in the central part of Alborz Mountains, is a large composite cone that consists of mainly trachyandesite lava flows, and subordinate pyroclastic materials (Davidson et al., 2004). The immediate basement to Damavand volcano in the Alborz Mountains is a folded and thrust-faulted passive-margin sedimentary sequence of carbonate, siliciclastic, and volcanic rocks. Young normal faulting attributed to transtension has been documented in central Alborz (Ritz et al., 2006) and around the Damavand (Hassanzadeh et al., 2006; Omidian, 2007).

3. Analytical techniques

Fresh samples of alkali olivine basalt (98DMV-101, -102, -133; Table 1), and trachyandesite (76An-2, -3) were collected from the peripheral Damavand cinder cone and the south east side of Haraz River, respectively (Fig. 1). Whole-rock major and trace element compositions were determined using inductively plasma optical emission spectrometry (ICP-OES) and inductively plasma mass spectrometry (ICP-MS) at Geosciences laboratories, Sudbury, Ontario. All samples for ICP analysis were dissolved using an alkali fusion (LiBO2/LiB4O7) method. Reproducibility, based on repeat analyses, for the major elements is ± 1.0% of the quoted values, while most trace elements have an uncertainty of ± 5.0% for the concentrations >100 ppm, and ± 10% for those with concentrations <100 ppm.

Radiogenic isotopic analyses were performed on whole-rock powders, digested in closed Savillex beakers using ultrapure HF and HNO3 in a proportion of 2:5, and heated for 48 h to ensure complete
For O isotopic analysis, approximately 7 mg of whole-rock powders was oven-dried for 24 h. Samples were then transferred to Ni bombs and fluorinated with BrF5 (e.g., Taylor, 2004). The Ni bombs were heated to 600 °C for 12 h. The extracted O2 was converted to CO2 and then measured on a Finnigan-MAT 252 multi-collector mass spectrometer at the Geological Survey of Canada, Ottawa. The δ18O values are reported relative to V-SMOW with a reproducibility of 2σ ± 0.2‰, based on multiple runs of NCSU-Qtz, an in-house standard quartz.

4. Petrography and geochemistry

The petrography of the volcanic rocks along with the geochemistry of the Damavand volcanic center has been previously described by Pandamouz (1998), Ashrafii (2003), Davidson et al. (2004) and Liotard et al. (2008). Only a brief description of the samples studied is given here. The alkali basalts are vesicular and have porphyritic textures, with microphenocrysts of olivine (15%), and clinopyroxene (10%) and laths of plagioclase set in a matrix of olivine, clinopyroxene, plagioclase and opaque minerals. Olivine crystals are euhedral to subhedral and unzoned. The trachyandesites have microphenocrysts of apatite (1%), biotite (5%) and plagioclase (up to 50%) residing in a matrix of clinopyroxene, plagioclase, and opaque minerals. Plagioclase shows concentric and complex zonation, and some grains have undergone sericitic alteration. It should be noted that some authors classified the volcanic rocks from Damavand as absarokite and banakite (Brousse and Moine-Vaziri, 1982; Liotard et al., 2008), but for simplicity and for the purpose of this paper, we classify these rocks as alkali olivine basalt and trachyandesite, respectively (cf. Pandamouz, 1998; Ashrafii, 2003; Davidson et al., 2004).

The results of the geochemical analyses of the Damavand volcanic rocks are presented in Table 1. Major element totals are low for the alkali olivine basalts. Plots of MgO (wt.%) vs. other major element oxides (Fig. 2) reveal a negative correlation of MgO with SiO2, but broadly positive correlations between MgO and CaO, and TiO2. The alkali olivine basalts have lower Na2O+K2O contents relative to the trachyandesites. Plots of MgO (wt.%) vs. other major element oxides (Fig. 2) reveal a negative correlation of MgO with SiO2, but broadly positive correlations between MgO and CaO, and TiO2. The alkali olivine basalts have lower Na2O+K2O contents relative to the trachyandesites (Fig. 1).

The chondrite-normalized (McDonough and Sun, 1995) rare earth element (REE) patterns of Damavand lavas show enrichment in lightREE (LREE) relative to heavy REE (HREE) (Fig. 3). Alkali olivine basalts and trachyandesites have, respectively, the highest and lowest REE concentrations. The REE patterns flatten through the middle to heavy REE in a MORB-normalized (Weaver, 1991) trace element plot (Fig. 4), all samples display enrichments in large ion lithophile elements (LILE), LREE and Pb, and depletions in Nb, Ta and Ti. The trachyandesites have lower LILE and high field strength elements (HFSE) than the alkali basalts, but are more enriched in U and Th. The position of the alkali olivine basalts, the most primitive rocks from Damavand on plots of Ti/Y vs. Zr/Nb, Ti/Y vs. Nb/Y and Ce/Ce vs binary as well as Th–Ta–Hf ternary diagrams is shown in Fig. 5.

In a Nd–Sr isotope plot diagram (Fig. 6), alkali olivine basalts plot close to Bulk Silicate Earth (BSE) whereas trachyandesites have higher 87Sr/86Sr ratios and lower 143Nd/144Nd ratios and plot within the more enriched parts of the diagram. The range of variations in Pb isotope ratios is small for the analyzed samples, yet the trachyandesites have slightly higher Pb isotope ratios than the alkali olivine basalts. Note that they all plot above the Northern Hemisphere Reference Line (NHRL), and very close to the geochron and the Stacey–Kramer’s (Stacey and Kramer, 1975) crustal Pb isotope evolution curve (Fig. 7). Whole-rock oxygen isotope compositions for alkali olivine basalts (δ18O = +6.5 to +6.8‰) are similar to those of the more evolved trachyandesites (δ18O = +6.6 to +6.9‰). Oxygen isotope ratios are all just above the range for the upper mantle (Mattey et al., 1994) but do not show correlations with any particular major and trace elements, nor with other isotopes.
5. Discussion and conclusions

5.1. The primary nature of Damavand lavas

Alkali olivine basalts from Damavand have characteristically low SiO₂ contents (ca. 47 wt.%) and elevated MgO (ca. 8 wt.%), Ni (182–229 ppm) and Cr (259–345 ppm) abundances (Table 1) that indicate they are the most primitive among the Damavand lavas and thus have been possibly derived by partial melting of ultramafic sources. It is conceivable that enrichment of incompatible trace elements such as Ba, Rb, La and Ce in alkali olivine basalts (Fig. 4) resulted from contamination of magmas with crustal materials. However, alkali olivine basalts have higher LILE and LREE abundances than average Upper Continental Crust (Fig. 4) and therefore crustal contamination is not likely to have a discernable impact on the chemical composition of magma. Also, the Sr and Nd isotope ratios of Damavand alkali olivine basalts plot in the mantle array, furthest from the likely isotopic compositions of older Iranian continental crust (Fig. 6). Although the Pb isotope ratios and the slightly elevated δ²⁸O values of alkali olivine basalts may argue that these lavas include small proportion of an evolved component, the high MgO, Ni and Cr contents do not support extensive crustal contamination during magma ascent. Thus the geochemical signatures of the Damavand alkali olivine basalts can be used to constrain the nature of their mantle source.

Trachyandesites are the most evolved rock types in Damavand, and the positions of their plotted compositions on various geochemical diagrams (Figs. 2–4) suggest that they are somehow related to the more mafic alkali olivine basalts. Mass balance calculations by Liotard et al. (2008) show that trachyandesites can be derived from the alkali olivine basalt following ~70% crystal fractionation of cumulate minerals including olivine, clinopyroxene, plagioclase, biotite, Ti-magnetite and apatite. Trachyandesites, in addition to having higher SiO₂, lower MgO and higher LILE contents compared to those of the alkali olivine basalts, have higher Sr and lower Nd isotope ratios that clearly indicate crustal assimilation accompanied by the fractional crystallization (AFC; DePaolo, 1981) has played an important role in modifying the chemical composition of the former lava in Damavand. Liotard et al. (2008) have demonstrated that 6–7% contamination of alkali olivine basalts with upper crust granitoids can lead to the generation of a magma having Sr, Nd and Pb isotopic compositions similar to those of the Damavand trachyandesite. However, the amount of crystal fractionation as well as crustal assimilation of alkali olivine basalt to create trachyandesite should be treated with caution because 70% fractionation of an assemblage, including plagioclase, as well as 6–7% assimilation of a granitoid is expected to impact the trace element patterns of trachyandesite, increase the δ²⁸O values substantially, and create significant Eu anomaly.

Fig. 2. Whole-rock major element plots of volcanic rocks from Damavand. Open circles and rectangles represent literature data reported by Mehdizadeh et al. (2002), Davidson et al. (2004), and Liotard et al. (2008). Correlations between the major element contents are consistent with a genetic relationship between samples.

Fig. 3. Chondrite-normalized (see McDonough and Sun, 1995) REE patterns of the Damavand volcanic rocks. The alkali olivine basalts contain the highest concentrations of REE. The light and dark gray areas cover the data reported by Mehdizadeh et al. (2002) and Liotard et al. (2008).

Fig. 4. N-MORB-normalized (see Weaver, 1991) trace element patterns for the Damavand volcanic rocks. OIB = Ocean Island Basalts, U.C.C. = Upper Continental Crust. Trace element pattern of volcanic rocks from Aeolian arc and Sunda arc is presented for comparison. The light gray area shows trace element data reported by Mehdizadeh et al. (2002) and Liotard et al. (2008).
5.2. Neo-Tethys oceanic crust subduction underneath Damavand volcanic field

The geochemical characteristics of the Damavand alkali olivine basalts led Mehdizadeh et al. (2002) and Liotard et al. (2008) to suggest that 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 H$_2$O–CO$_2$ 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; Taitton and McKenzie, 1994). A number of geochemical peculiarities of Damavand lavas such as Nb, Ta, and Ti depletions, or partial melting of subducted slabs (Menzies and Hawkesworth, 1987; Hawkesworth et al., 1990) or from plume heads (McKenzie, 1989; Taitton and McKenzie, 1994). A number of geochemical peculiarities of Damavand lavas such as 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 Meh dizadeh et al. (2002) and Liotard et al. (2008). These authors also indicated that the enrichment event was related to subduction of either 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. Rather than involving Paleo-Tethys, Jung et al. (1976), Brousse and Moine-Vaziri (1982), and Aftabi and Atapour (2000) have attributed the Damavand volcanic activity to Cenozoic Neo-Tethys oceanic subduction under Central Iran, and argue that the increasing K2O content of volcanic rocks from the UDMB to Damavand volcano may reflect the depth to a Benioff zone, increasing northward in a manner analogous to the “K–h” relationship of Dickinson and Hatherton (1967).

One of the most important parameters that determine the chemical composition of the arc magma source is the composition and quantity of the components involved (the mantle wedge, chemical composition of the arc magma source is the composition of the UDMB to Damavand volcano may recombination). Liotard et al. (1999) and Plank and Langmuir (1998) have compiled trace element and/or isotope data from a variety of subducting sediments including those of Makran and Java. Close examination of such data shows that oceanic sediments from Makran and Java are very similar in terms of trace element abundances. Fig. 8 illustrates incompatible trace element patterns generated by mixing between subducted sediments and a presumed depleted mantle source. The chemical compositions of mixing components are given in Table 2. Our modeling demonstrates that various amounts of pelagic sediments added to a depleted mantle fail to create trace element patterns similar to those of the Damavand alkali olivine basalt (Fig. 8). More importantly, addition of such amounts of pelagic sediments changes the Sr, Nd and Pb isotopic ratios of a depleted mantle source to levels significantly different from those of the Damavand alkali olivine basalt (Figs. 6 and 7). Trace element modeling by Liotard et al. (2008) suggests that the source of Damavand alkali olivine basalts (their absarokites) was likely a metasomatized lherzolite. However, our mixing calculations also show that the Sr and Nd isotopic ratios of a primitive lherzolite mantle source contaminated by small amounts of subducted pelagic sediments (~0.5%) are substantially higher than those of young Damavand basalts (Fig. 6). On Nd vs. Sr isotope diagram, these basalts do not show a mixing trend between depleted mantle components and subducted sediments, as exhibited by the volcanic rocks from the Lesser Antilles (Fig. 6). It should also be mentioned that some authors (e.g., Davidson, 1996) who would argue that the extreme compositions from the Lesser Antilles are crustal contamination. Additionally, the limited ranges of δ18O (i.e., +6.5 to +6.8‰) in alkali olivine basalts argue against contributions from subducted materials in the mantle source of Damavand volcanic rocks. Pineau et al. (1999) have shown that higher scatter δ18O range from 5.3 to 8.5‰ in lavas from Kamchatka Peninsula, far-east Russia, is inherited from metasomatized normal mantle magmas with a slab-derived, water-rich fluid/magma. A quantitative modeling by Eller et al. (2000) and Eller (2001) also demonstrated that addition of 18O-enriched slab-derived fluids or melts to an upper mantle with δ18O = 5.5‰ can create lavas highly scattered in δ18O. The calculations by these authors, furthermore, predicted a strongly hyperbolic covariation of δ18O values and 87Sr/86Sr ratios. Close examination of isotopic data (Table 1), reveals that such isotopic correlations cannot be found among alkali olivine basalts from Damavand. Although depletions in Nb, Ta, Zr and Ti are normally considered as geochemical evidence for subduction-related magmatism, because the metasomatic agents that originate from within the subducted oceanic crust are depletions in Nb, Ta, Zr and Ti in the Damavand volcanic rocks could be related to subduction of either the ocean-like Caspian crust or the continental crust. Moreover, the trace element patterns and the degree of LILE enrichment of alkali olivine basalts in Damavand are different from typical arc magmas, including Aleutians and Tongan Arc (Fig. 4). The depletions in Nb, Ta, Zr and Ti in the Damavand volcanic rocks could well result from either the retention of Ti-bearing phases in the mantle source or the slight reaction of the magma with the crustal materials, both unrelated to subduction activity. On plots of Ti/Y vs. Zr/Nb, Ti/Y vs. Nb/Y and Ce/Pb vs. Ce binary as well as Th–Ta–Hf

![Figure 8](https://example.com/fig8.png)

**Figure 8.** Primitive mantle-normalized (see McDonough and Sun, 1995) diagram showing the compositions of a depleted mantle source component (see Workman and Hart, 2005) contaminated with 1%, 3% and 5% of subducted Java pelagic sediment (see Plank and Langmuir, 1998).
ternary tectonic discriminant diagrams, which are only valid for the primitive rocks, the alkali olivine basalts from Damavand plot well away from arc settings (Fig. 5). Also, these lavas not only do not plot on orogenic field but also are restricted to the anorogenic domain on Th/Yb vs. Ta/Yb and Th'1000/2r vs. Nb'1000/2r tectonic discriminant diagrams (not shown). Along with the afore-mentioned geochemical considerations, the distance of the Damavand volcanic rocks from the Zagros Trench (ca. 400 km) and its age relation (1.8 Ma–7 ka) to the Neo–Tethys closure (20 Ma) are problematic when trying to relate the Damavand magmatism to Neo–Tethys subduction.

Although the distance of the Damavand volcanic rocks from the Zagros Trench can be resolved by the low angle subduction of oceanic crust, as has been invoked to explain inland volcanism in western North America (Feeley, 2003; Murphy et al., 2003) and Andean margins (Gutsch et al., 2000), recent studies on magmatism in SSZ and UDMB reveal that subduction of the Neo–Tethys slab occurred much earlier than the time of Damavand volcanism (Agard et al., 2005; Shafiei et al., 2009; Verdel, 2009). Igneous rocks from SSZ and UDMB formed during two distinct episodes: Jurassic–Cretaceous and Tertiary, respectively (Beberian and Beberian, 1981; Agard et al., 2005; Ahmadi-Khaladi et al., 2007), suggesting that the axis of magmatism shifted 300 km to the northeast from its initial position within the SSZ at the end of Mesozoic. Because geochemical data of Mesozoic and Tertiary igneous rocks from the SSZ and UDMB are very similar and no continuous suture zone exist between these two, Omrani et al. (2008) and Verdel (2009) concluded that magmatism shifted from the SSZ to the UDMB in late Cretaceous as the result of the flat-slab subduction of the Neo–Tethys. The slab then broke off and subducted with a steep slope into the mantle underlying UDMB. Such subduction resulted in the Eocene to Late Miocene arc magmatism in the UDMB (Omrani, 2008). Keskin (2003) have also suggested similar model of Neo–Tethys slab steepening and break-off beneath Anatolia Plateau for magma generation in eastern Turkey. Agard et al. (2005) and Omrani et al. (2008) stress that any Plio–Quaternary magmatic activity to the north of the central UDMB is unrelated to subduction activity, because the last pieces of the Neo–Tethys oceanic slab sank into the mantle underlying the central parts of the UDMB (Omrani et al., 2009). The presence of linear and narrow arc magmatism along the strike in UDMB, which reflects a slab break-off and deep subduction in the late Miocene, is inconsistent with the subduction of the Neo–Tethys under the Damavand in Quaternary. It is thus inevitable to look for other processes and activities rather than subduction and convergent margin for the genesis of the Damavand volcanic rocks.

5.3. Deep mantle melting and lithospheric delamination

Another mechanism to consider for inland magmatism is deep mantle melting and the delamination of sub-continentallithosphere, in response to the crustal shortening (e.g., Davies and Blanckenburg, 1995). Deep mantle melting as a source of alkaline igneous rocks has been proposed by a number of authors. For example, phase equilibria studies on lamproites from the Gausberg lamproites in the East Antarctic shield (Murphy et al., 2002) point to partial melting of mantle materials in the transition zone or lower mantle. Elkins-Tanton and Grove (2003) also performed phase equilibrium experiments on high K olivine luecitite from central Sierra Nevada and suggested that the magma was derived from a hydrous source at depths of greater than 100 km within the mantle. It is further suggested by Elkins-Tanton and Grove (2003) that lithospheric delamination some time before the Pliocene led the source material to rise into the lithospheric dome and melted adiabatically to produce the high-potassium magmas. Geophysical (Wernicke et al., 1996; Boyd et al., 2004; Zantl et al., 2004), geological and petrological (Ducea and Saleeby, 1998; Manley et al., 2000; Ducea, 2001; Lee et al., 2001) evidence also link the Pliocene potassic volcanism in the southern and central Sierra Nevada to the lithospheric mantle delamination (van Kooten, 1980; Dodge et al., 1986; Feldstein and Lange, 1999; Farmer et al., 2002). Kay and Kay (1993) used criteria such as onset of mafic volcanism and a regional change in the stress system, to postulate a Pliocene episode of lithospheric delamination in the southern Puna. Gao et al. (2002) also suggest that wholesale replacement of lithospheric mantle (at lower crust) beneath the North China craton may require large-scale continental collision.

The Iranian part of the Alpine–Himalayan active tectonic belt is currently deforming at a high rate. Agard et al. (2005) reported a minimum estimate of the post-Miocene collisional shortening rate to be 5–9.3 mm/year. In the Alborz Mountains, a total shortening of 30 km at the longitude of Tehran since the early Pliocene (Allen et al., 2003) is attributed to the northward shortening between the central Iranian block and the Eurasian plate (Vernant et al., 2004). Nazari (2006) also estimated the total amount of shortening at about 38% for the Alborz, mainly occurred after Eocene. Such compressional stresses induced on the Iranian plate led to major earthquake activity (Motazedian, 2006) as well as periodic lithospheric delaminations (Agard et al., 2005; Omrani et al., 2008). In a more local scale like in Damavand, transtensional systems have developed along releasing faults and step-overs (Ritz et al., 2006; Hassanzadeh et al., 2006; Omidian, 2007).

Geophysical studies have revealed that a mantle lithosphere is almost completely absent beneath the Alborz Mountains (e.g., Sodoudi et al., 2009). 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) and receiver function analysis of teleseismic data (Doloei and Roberts, 2003). A more recent study by Sodoudi et al. (2009), based on receiver functions, indicates a crustal thickness of ~51–54 km beneath the range. Rajaei et al. (2010) reported an even thicker crust (~55–58 km) indicating a moderate crustal root but still inadequate to compensate the existing elevation. 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). The Damavand volcanic rocks could not have originated from a depleted upper mantle because the asthenosphere is depleted in incompatible trace elements and has dramatically different Sr, Nd, Pb and O isotope compositions. Therefore, partial melting of such an upper mantle source cannot produce a melt similar in chemical composition to that of the alkali olivine basalt from Damavand. Davidson et al. (2004) suggest that the geochemical constraints of Damavand volcanic rocks are in line with a local hotspot/plume origin, associated with lithospheric delamination. The Sr and Nd isotope data from the Damavand volcanic rocks plot within the field of mantle array which represents OIB (Fig. 6) and the trace elements patterns of Damavand alkali olivine basalts are also more similar to those of OIB (Fig. 4). The position of the studied samples around the Pb isotope crustal evolution curve (Fig. 7) which indicates a crustal source for Pb, along with the LILE-Pb enrichment and Nb–Ta depletions, however, can be explained by slight upper crustal contamination accompanied by small degrees partial melting of an OIB-like mantle source. Reagan and Gill (1989) have shown that incompatible trace element enrichment in magma can be inherited from small-degree partial melting of an OIB-like mantle source. Furthermore, numerical modeling by McKenzie (1989) and Tait and McKenzie (1994) demonstrated that melts emanating from mantle upwelling can be enriched in volatiles and incompatible elements. It thus seems likely that partial melting of an OIB-like mantle source generated magma.
with trace element contents similar to those of Damavand basalts. In this case, transpression probably provided conduits for mantle-derived magmas to ascend to the surface (Hassanzadeh et al., 2006; Omidian, 2007).

Since crustal thickening and shortening in response to the compression from the Afro-Arabian plate is an ongoing process, it is speculated that repeated episodes of mantle delamination and within-plate magmatism could be found in parts of Iran located to the north of the Zagros suture zone, and beneath the Alborz Mountains.

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