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انجمن بلورشناسی و کانی شناسی ایران

ژئوشیمی و پتروژنز جریانهای بازالتی در افیولیت های نائین-دهشیر

هادی شفائی مقدم[1]، محمد رهگشای[2]، علی بنی طبا [3]

۱- دانشکده علوم زمین، دانشگاه علوم پایه دامغان، دامغان

۲- دانشکده علوم زمین، دانشگاه شهید بهشتی تهران، تهران

۳-- بخش مهندسی معدن، دانشکده مهندسی، دانشگاه کاشان، کاشان

پست الکترونیکی: hadishafaii@yahoo.com

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چکیده: دیابازها، پیلولاواها و جریانهای بازالتی در افیولیتهای نائین-دهشیر در نمودارهای عنکبوتی با الگوی مسطح تا تقریبا تهی شده مشخص شده، از طرف دیگر این گدازه‌ها توسط تهی شدگی در عناصر با قدرت میدانی بالا و غنی شدگی در عناصر با شعاع یونی بالا مشخص می‌شوند. این رفتار ژئوشیمیایی با بازالتهایی که در یک محیط مرتبط با قوس آتشفشانی فوران می‌کنند، سازگار می‌باشد. دانه‌های کلینوپیروکسن در این سنگها دارای میزان پائینی از تیتان بوده و رفتاری مشابه کلینوپیروکسن‌های موجود در تولئیتهای جزایر قوسی دارند. تمام ویژگی‌های ذکر شده برای گدازه‌های منطقه نائین-دهشیر با تشکیل یک حوضه پشت قوس در کرتاسه میانی تا بالایی، در اثر فرورانش مایل اقیانوس نئوتتیس در امتداد حاشیه فعال قاره‌ای بلوک ایران مرکزی سازگار می‌باشد.

واژه‌های کلیدی: *بازالتها، دیابازها، الگوی عناصر نادر خاکی مسطح، تهی شدگی از عناصر با قدرت میدانی بالا، حوضه پشت قوس.*

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Geochemistry and petrogenesis of basaltic flows in the Nain-Dehshir ophiolites

H. Shafaii Moghadam[1], M. Rahgoshay[2], A. Banitaba[3]

1- School of Earth Sciences, Damghan University of Basic Sciences, Damghan
2- Faculty of Earth Sciences, Shahid Beheshti University, Tehran
3- Mining Department, Faculty of Engineering, Kashan University, Kashan
E-mail:hadishafaii@yahoo.com

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Abstract: Diabases, pillow lavas and basaltic flows in the Nain-Dehshir ophiolites are marked with flat to slightly depleted pattern in REE chondrite-normalized diagram and are characterized by depletion in HFSE and enrichment in LILE. This geochemical behavior can be considered for lavas erupted in arc-related environments. Clinopyroxene in these rocks shows low content of TiO_2 and resemble those found in island-arc tholeiites. These characteristics are consistent with back-arc formation during middle to upper Cretaceous, due to the oblique subduction of Neotethyan Ocean along the active continental margin of the central Iranian block.

Keywords: *Basalts, Diabases, Flat REE pattern, HFSE depletion, Back-arc basin.*

Introduction

Since last decades many studies have been focused on the geology and tectono-magmatic environment of Central Iranian ophiolite belt (the Nain-Baft belt). For the first time, this belt was considered to be formed as a result of Red sea type rifting in the Central Iranian Block, maybe due to the compressional movements during the late Paleozoic to middle Triassic [1]. These ophiolites together with other ophiolites like the Sabzevar and the Birjand complexes, distributed around the Lut block, are categorized as the inner ophiolitic belt [2]. The Nain-Baft ophiolites are interpreted as; i- a narrow and small oceanic basin, trapped between the Lut block and the Sanandaj-Sirjan zone, the active continental margin of Central Iranian block [1, 3, 4], ii- as Cretaceous arc basin related to Tethyan subducton regime [5, 6] and iii- as late Cretaceous back-arc basin [7, 8]. The main attempts of this study are to review and synthesis the crustal units of the Nain-Dehshir ophiolites and to make a geochemical distinction between various types of basaltic eruptions and finally to propose a geodynamic setting for formation of the crustal sequence in the Nain-Dehshir ophiolitic belt.

Nain ophiolites: these ophiolites have been firstly studied by Davoudzadeh [3]. Several tectonic slices, composed of serpentinites, peridotites together with pegmatite gabbros, isotropic gabbros, gabbro-norites, pillow lavas, individual gabbroic and diabasic dikes and dike swarm complex, separated by many reverse-thrust faults (Fig.1A), can be regarded to be active from upper Cretaceous to Miocene. Deep-water Globotruncana-bearing limestones (with Santonian -Maestrichtian age) are the older pelagic sediments in these ophiolites. Shallow-water middle Paleocene-lower Eocene limestones, with basal conglomerate, cover unconformably the pelagic limestones. In the west, the Nain complex is surrounded by the younger, Tertiary volcanic and plutonic piles. In the east, the sedimentary sequences began with middle Eocene-lower Oligocene Akhoreh formation, continued with lower Red Formation, Qom Formation and Upper Red Formation, all rest unconformably on the ophiolites.

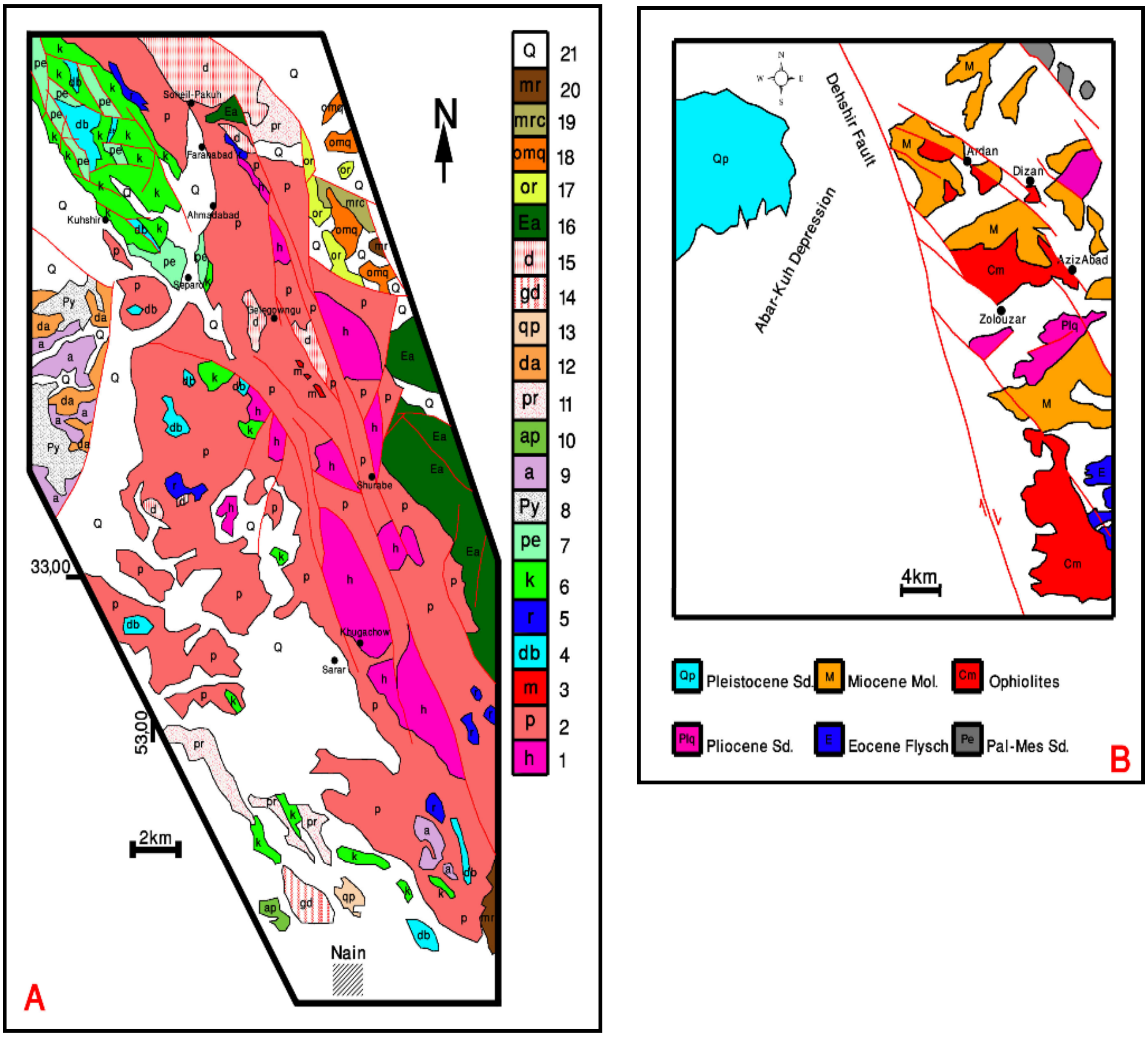

Figure 1. Geological maps of the Nain (A) and the Dehshir (B) ophiolites. In A: I- Upper Cretaceous ophiolitic units: 1-harzburgites, 2-serpentinites with diabasic-gabbroic dikes, 3-metamorphic rocks, 4-diabases, 5-radiolarites, 6-Senonian-Maestrichtian pelagic limestones, II- Cenozoic transgressive detritic sediments: 7-Middle Paleocene to lower Eocene limestones, III- Tertiary magmatic rocks: 8- Eocene pyroclastic rocks, 9-andesites-trachyandesites, 10-andesite porphyry, 11-porphyrites, 12-dacitic flows, 13-quartz porphyry, 14-Lower Oligocene granodiorite, 15-diorite, IV-middle Eocene to lower Oligocene Terrigenous sediments: 16-Akhoreh formation, V- Tertiary sedimentary rocks: 17-Upper Oligocene conglomerates, sandstones and marls (Lower Red Formation), 18-Oligomiocene limestones and sandy limestones (Qom formation), 19-Miocene-Pliocene conglomerates, 20-red sandstones and marls (Upper Red Formation), 21-Quaternary sediments.
In B: Sd. = Sediments; Mol. = Molasses; Pal-Mes Sd. = Paleocene Kerman conglomerate.

Crustal sequence in this massif is thin and marked with tectonically disrupted units, composed of pillow lavas, isotropic gabbros, gabbro-norites and diabasic-gabbroic dikes. In the east of Ahmad Abad village (Fig.1A), there is a polygenic complex consisting of many diabasic dikes, crosscutting gabbros, amphibole gabbros and micro-gabbros (dike swarm complex) and also plagiogranites and pillow lavas (Fig.2A). Diabasic dikes are also injected into the neighboring plagiogranite unit. Petrographically, most of the dikes are of diabasic character although gabbroic and dacitic ones are also present. Well-preserved clinopyroxene grains, highly altered plagioclases, iron oxides, secondary amphiboles, epidote and chlorite, with or without quartz are the main constituents of these dikes (Fig.2C).

Pillow lavas are found in several localities and display small to large, well-preserved or brecciated pillow structure. In most cases their matrix has been completely converted into red clay materials (palagonite) and chlorite. They are aphyric to moderately phyric with plagioclase and clinopyroxene phenocrysts. Plagioclase phenocrysts and microlites show higher degree of alteration to clay minerals, sericite and epidote. Clinopyroxene grains show slight alteration to chlorite and euralite. Iron-oxides, secondary amphiboles, chlorite, epidote, quartz, calcite and prehnite are other minor phases in the pillow lavas.

Clinopyroxene in diabasic dikes is augite in composition with low content of TiO_2 (0.69-0.12 %Wt.). Based on discrimination diagram, proposed by Beccaluva et al. [9], these clinopyroxenes plot in the IAT (Island Arc Tholeiites) and in boninites fields (Fig.3A).

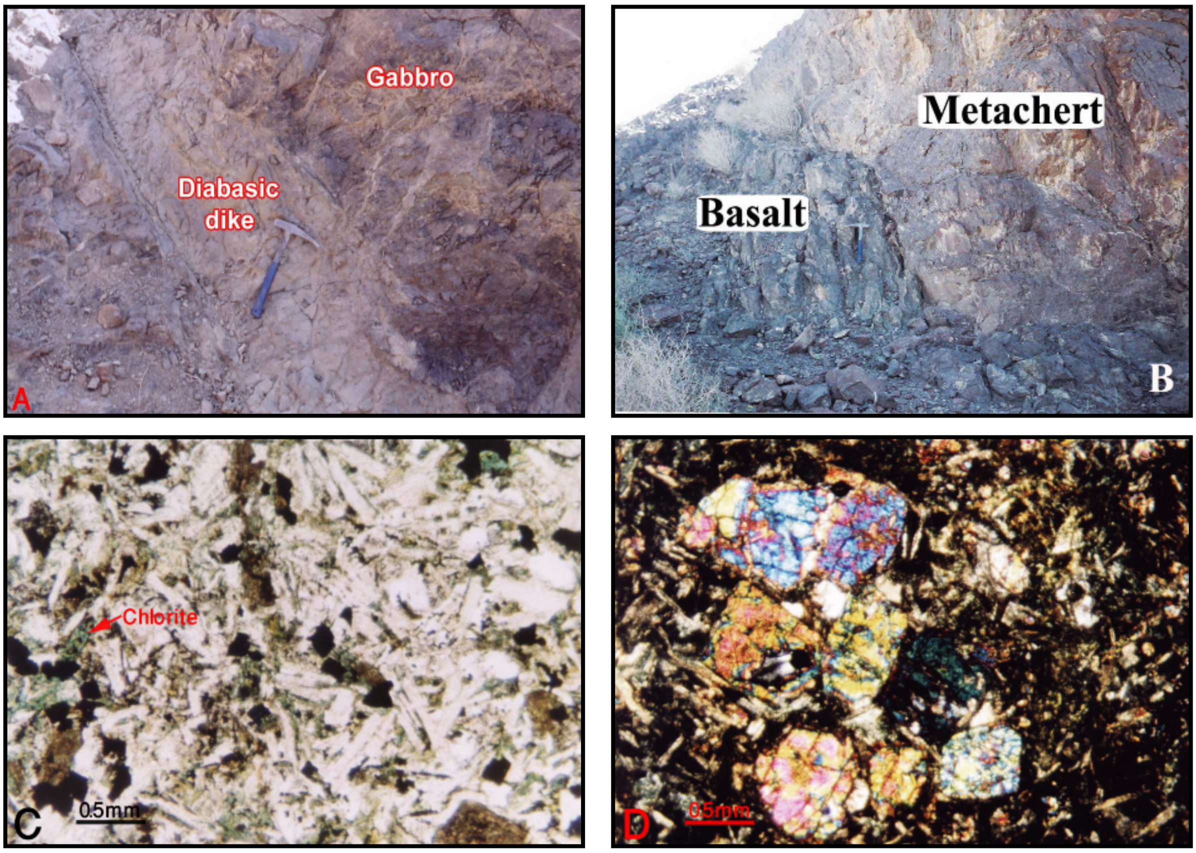

Figure 2. A- Shown here is the diabasic dike injected into amphibole gabbros (dike swarm complex) in the Nain ophiolites. B- In this picture, the chert unit has been rested unconformably on the basalt unit in the Dehshir ophiolites. C- Plagioclase laths associated with quartz, iron oxide and chlorite in Nain diabases. D- Clinopyroxne grains with glomeroporphyritic texture, among plagioclase microlites, in Dehshir basalts.

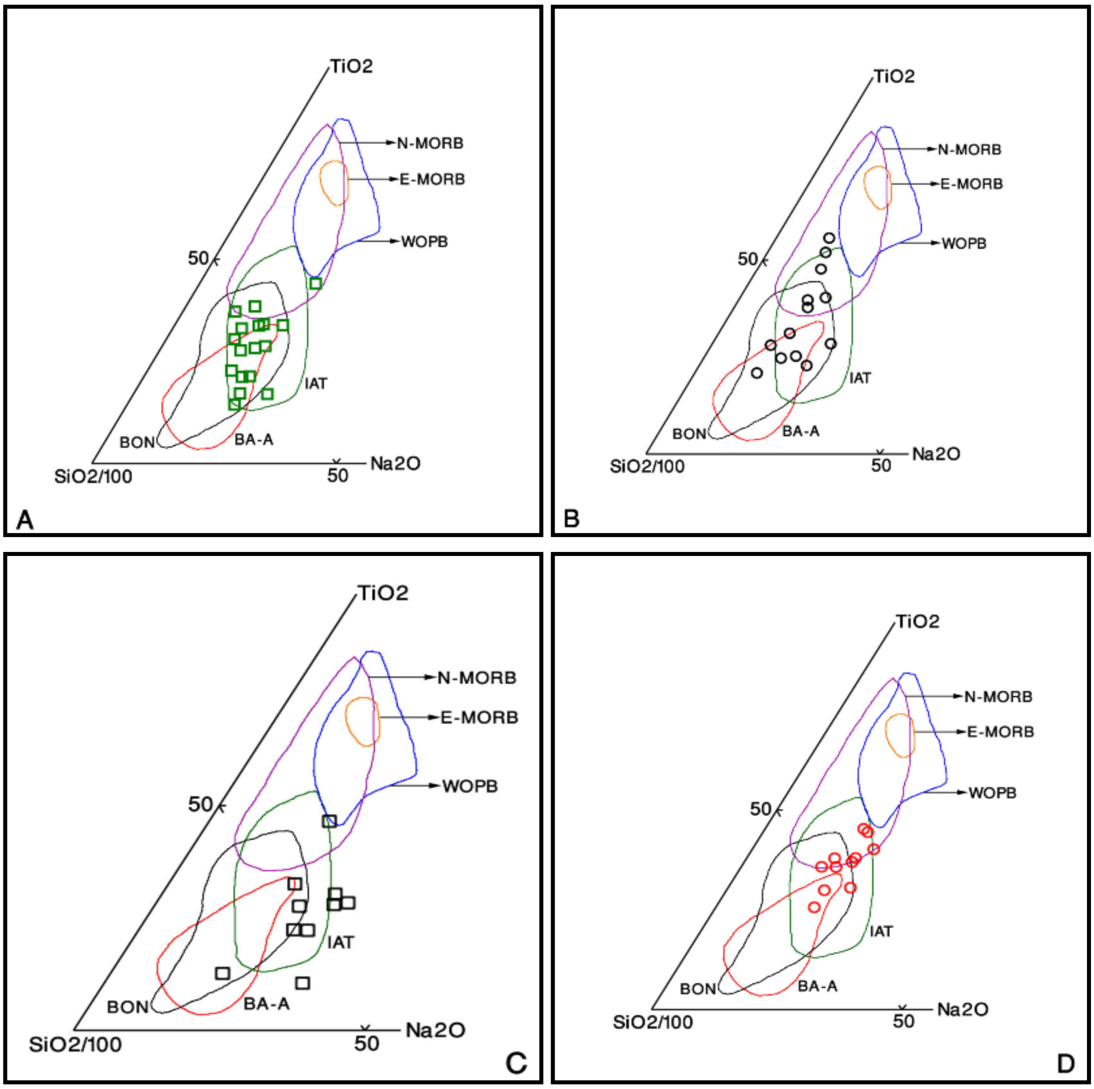

Figure 3. A- Magmatic affinity of clinopyroxenes, based on the TiO_2, $SiO_2/100$, Na_2O diagram of Beccaluva et al. [9], in diabasic dikes and B- in pillow lavas of Nain ophiolites. C- and D- These figures show the geodynamic signature of clinopyroxenes in Dehshir pillow lavas and diabases respectively.

The whole rock TiO_2 content of these diabases is also low and could be regarded as low-Ti and very low-Ti series. On the Ti/V diagram [10] diabasic dikes plot either in boninite field or lie on the line separating IAT from boninites (Fig.5A). These rocks have low REE content (with $La_{(N)}$ and $Yb_{(N)}$ between 3.59-6.58 and 8.45-12.86 times chondritic abundances respectively). LREEs show depletion compared to HREEs (similar to N-MORB). Sample BS05-13 shows different degree of partial fusion (and maybe mantle source) (Fig.6). This result can be also deduced from multi-elements diagram for diabases. Here also BS05-13 sample show different degree of depletion or enrichment in some elements (e.g., Ti depletion). Depletion in Nb and Ta and enrichment in Pb, U and Sr for all samples is distinctive feature (Fig.6).

Clinopyroxene in pillow lavas is augite and has higher content of TiO_2 than those in diabasic dikes (0.17-0.89 %Wt.). on the TiO_2-$SiO_2/100$-Na_2O diagram [9], these pyroxenes exhibit Island Arc Tholeiites affinity (Fig.3B). In pillow lavas, plagioclases are of bytownite in composition (An_{71}-An_{73}).

Pillow lavas are regarded as low-Ti basalts (0.3-0.9 %Wt.) here and are tholeiitic (Fig. 4A). On the Ti versus V diagram [10] they are plotted either in IAT filed or lie on the boundary between IAT and MORB compositions (Fig. 5A). Chondrite-normalized pattern for pillow lavas exhibits relatively flat pattern, similar to island arc tholeiites (Fig.6). When primary mantle normalized multi-elements diagram for pillow lavas is taken into account, pillow lavas display high content of Ba, Rb, U and Pb (large ion lithophile elements) while Zr, Ti, Y, Hf and specially Nb, Th and Ta are slightly depleted (Fig.6). Moreover, these pillows show some characteristic features of calc-alkaline rocks, highlighted by K, U, Sr and Pb enrichments (along with depletion in high field strength elements).

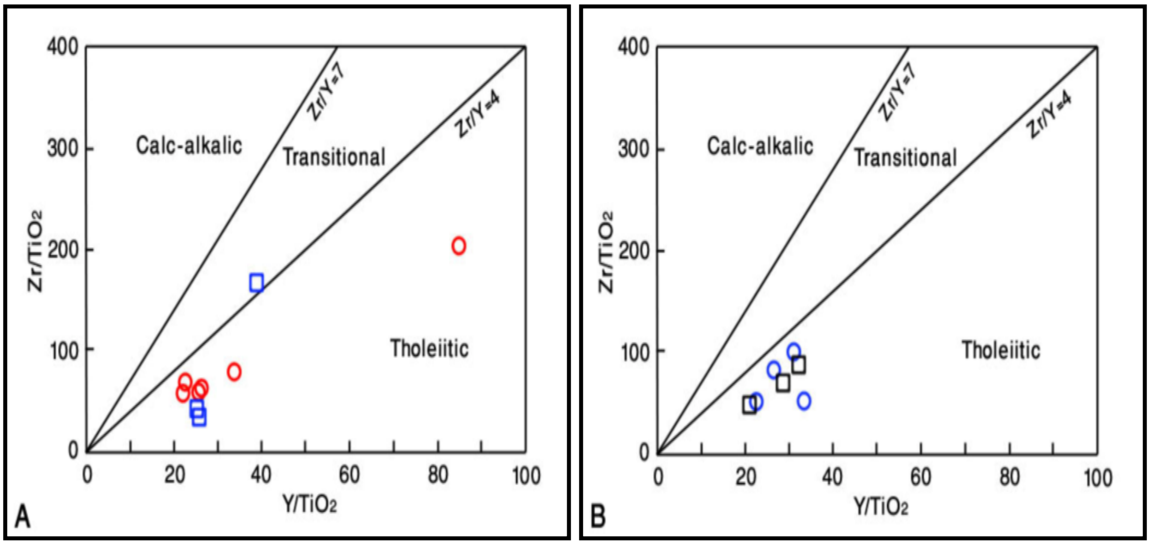

Figure 4. Zr/TiO_2 vs. Y/TiO_2 diagram to show magmatic affinity of Nain (A) and Dehshir (B) diabasic and basaltic rocks. Circles denote pillow lavas and squares are diabasic rocks.

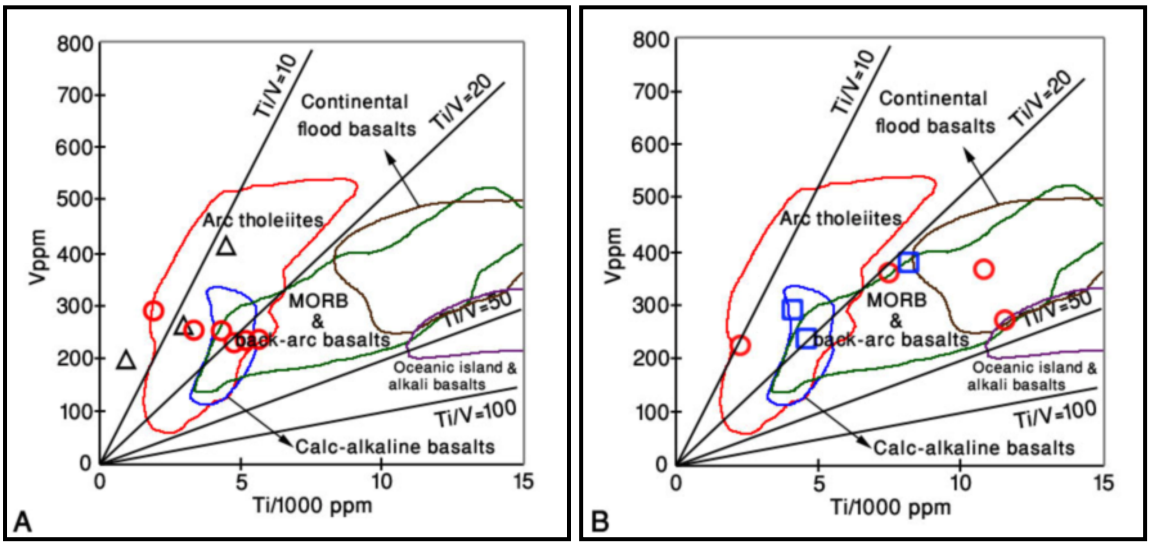

Figure 5. V/Ti diagram [10] for both Nain (A) pillow lavas (circle) and diabasic dikes (triangle) and also Dehshir (B) pillows (circle) and diabases (square). In Nain complex, pillow lavas and diabases occupy the IAT field while in Dehshir ophiolites, some rocks have more Ti content and plot in MORB and back-arc basin basalts field.

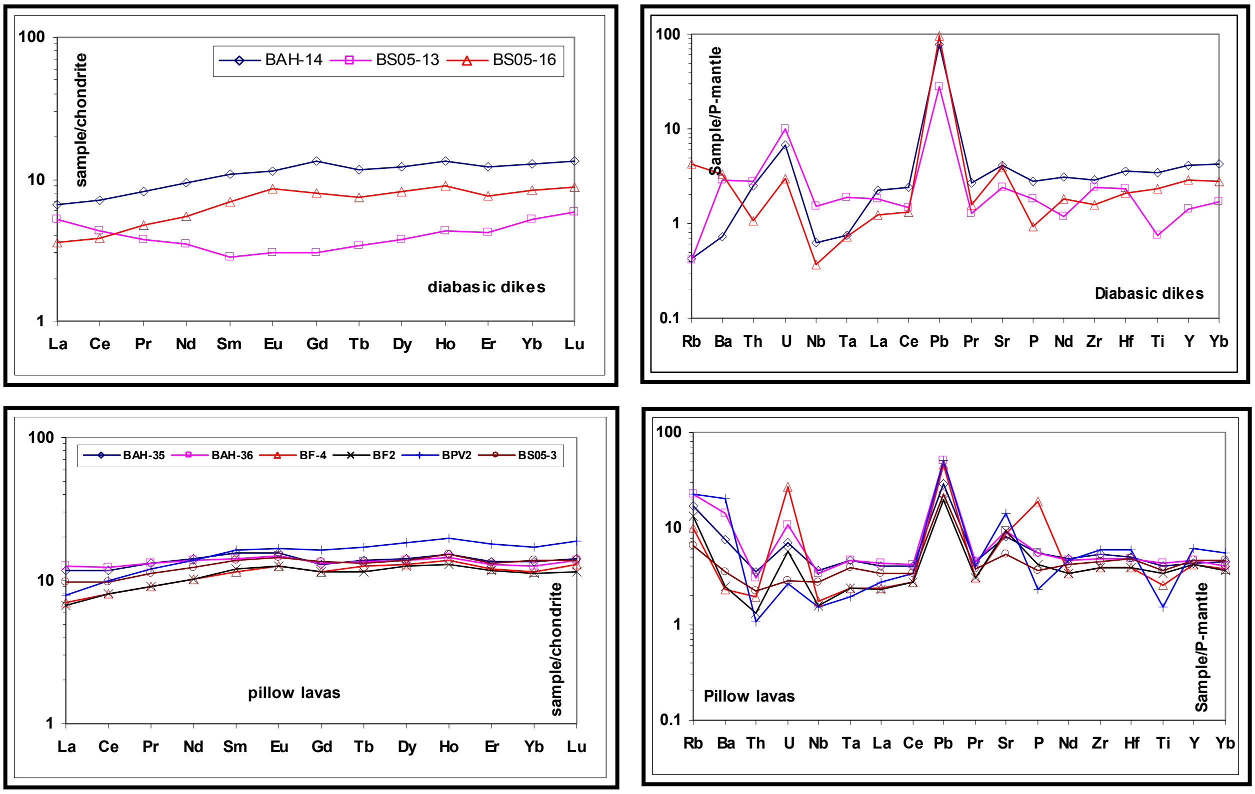

Figure 6. Chondrite normalized and primary mantle normalized patterns for Nain diabases and pillow lavas. Normali zation values from [18,19].

Dehshir ophiolites: these ophiolites represent dismembered-crushed sequences along the Nain-Baft fault. Due to the intensive movements of the Dehshir fault, all ophiolitic units show brittle behavior and subsequent crushing and metamorphism. The ophiolitic units are boudinaged across the Dehshir region (Fig.1B), distributed among the Oligomiocene deposites, or younger (Quaternary) sediments. The latter is usually epiclastic deposits, derived from the Tertiary dacitic-rhyodacitic domes. Deep-water Globotruncana-bearing limestone is the oldest ophiolite-related unit, similar to the Nain complex. Continuation of Akhore formation, composed of conglomerate (with fragments of chert, peridotite and diabase) and graywacke, can be traced among the southern part of Dehshir quadrangle (southwest of Gariz village). Serpentinites, peridotites, pillow lavas, flow lavas, pegmatite gabbros, diorites and diabasic dikes (as individual ones crosscutting peridotites or as sheeted dike complex) associated with metacarbonates, meta-volcanites and other metamorphic rocks are the main units of the Dehshir ophiolites (Fig.2B). In Aziz Abad region, diabasic dikes along with basaltic and dacitic dikes have been injected into each other with chilled margins (in one side) and brecciated margins (in other side). Moreover, in this region, toward up section, these doleritic dikes have been injected into pillow lavas. Pillow lavas in Dehshir complex are characterized by brecciated and crushed structure. Amphibole schists and amphibolites, together with meta-amphibole gabbros and peridotites have been distributed in Zolozar region. Here, granitic intrusions crosscut metamorphic rocks and moreover one basaltic dike cuts the host amphibole gabbros.

Both plagioclase phenocrysts and microlites show moderate to complete alteration in pillow lavas. Alteration to clay minerals, epidote, and chlorite is common for plagioclase and sometimes for clinopyroxene grains. Porphyritic texture, and also glomeroporphyritic texture (Fig.2D), is the obvious feature. In pillow lavas, amygdaloidal structure is common, filled by calcite, chlorite and quartz.

In diabasic dikes, plagioclase laths are dominant, altered into clay minerals and epidote. Clinopyroxene display alteration to euralite and chlorite. Chlorite, epidote, iron oxides, prehnite are other minor phases. In diabasic dikes with chilled margin, the border of dike is characterized by flow or trachytic texture (compositionally more evolved), composed of fine-grained, altered plagioclase microlites associated with iron oxide, clay minerals and quartz (keratophyric character). Clinopyroxene in pillow lavas shows augite and diopside composition with more Mg content compared to those found in Nain pillow lavas. Moreover clinopyroxene is also augite in the diabasic rocks. Like the Nain ophiolites, on the TiO_2-SiO_2/100-Na_2O diagram [9], clinopyroxene of pillow lavas and diabases show tendency to those found in island-arc tholeiites (Fig. 3C & D).

Dehshir basalts (pillow lavas) show high Ti content (1.26-1.94 %wt.). The exception is the basaltic dike sample with 0.39 %wt. TiO_2. These basalts are of tholeiitic origin (on the Zr/TiO_2 vs. Y/TiO_2 diagram) (Fig.4B) and on the Ti-V diagram [10] they show tendency to MORB (and back-arc basin basalts) and IAT fields (Fig.5B). on the spider, designed for Dehshir basalts, they show both flat pattern (similar to IAT) and depleted pattern (similar to N-MORB) (Fig.7). Various types of mantle source, enriched mantle in the case of DR05-2A and DAR05-6 samples, and depleted one for DAR05-5 and (more-depleted source for) DZ05-1D (basaltic dike) can be regarded. The different degrees of partial fusion for DR05-2A and DAR05-6 samples (with flat pattern) and on the other hand for two other samples are obvious (with depleted pattern), deduced from REE normalized patterns (Fig.7). On the multi-elements diagram depletion in Th, Nb (and slightly in Ti) and enrichment in U, Pb, Ba and Rb are more distinctive feature (Fig.7).

Dehshir diabases on the V-Ti diagram [10] plot in IAT and MORB fields and are of tholeiitic origin (Fig. 4B & 5B). On the spider diagram, both flat pattern (DAR05-3 and DZ05-4 samples) and depleted pattern (DAR05-4 sample) can be considered for diabasic samples (Fig.7). This difference in patterns obviously highlights the difference in partial fusion degree. Diabases, on multi-elements diagram, character with both depletion in Nb, Ta and Ti (except in DAR05-4 sample), and enrichment in U, Pb and Sr (Fig.7).

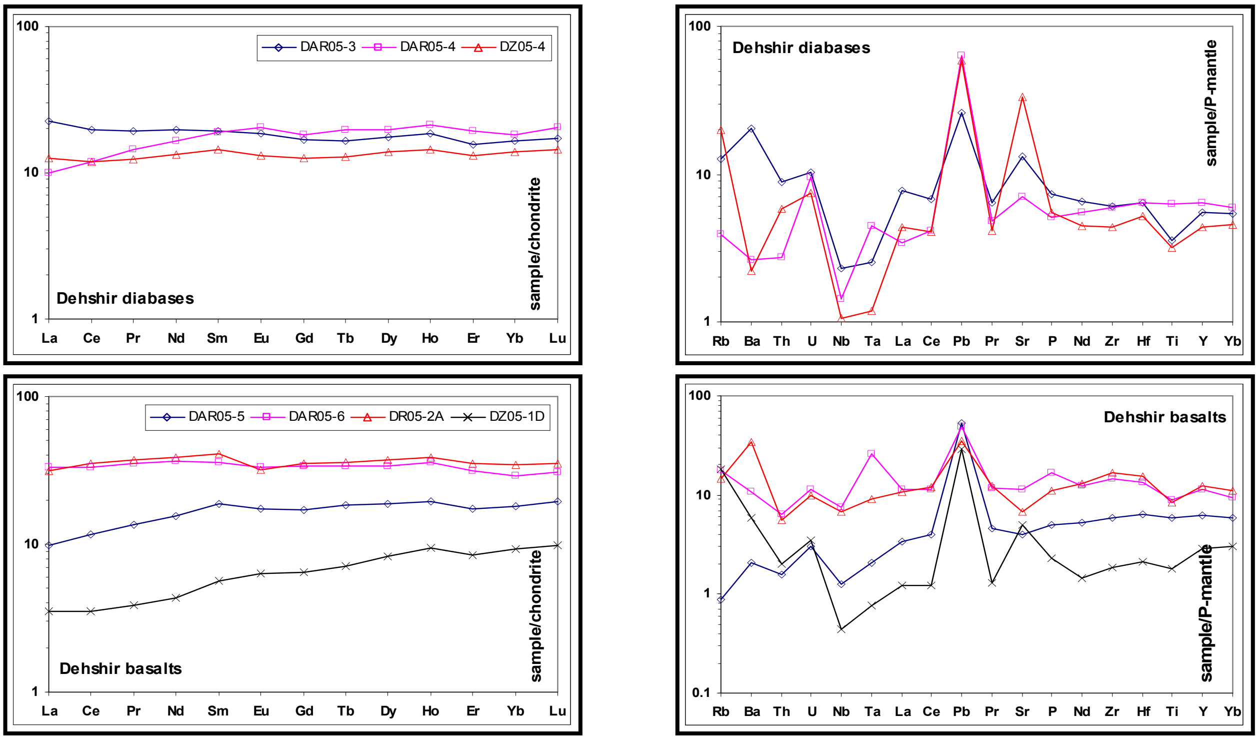

Figure 7. Chondrite normalized and primary mantle normalized patterns for Dehshir diabases and pillow lavas. Normalized values from [18,19].

Discussion and conclusions

Pillow lavas in Nain-Dehshir ophiolites are characterized by flat to slightly depleted pattern in related spider diagrams. On the other side, multi-elements diagrams show enrichment in large ion lithophile elements and depletion in high field strength elements. Diabasic rocks also have similar characters and show arc-like signatures. It is noteworthy that the highest degree of LILE enrichment is consistent with melting of subduction-contaminated mantle [11-13]. However, HFSE depletion is ascribed to arc-derived lavas (e.g., [14-15]). Clinopyroxenes in pillow lavas and diabases are characterized by low Ti content, similar to IAT, on the basis of Na_2O, SiO_2, TiO_2 diagram, proposed by Beccaluva et al., [9].

Concluding remarks

After establishment of ideas on oblique subduction [1,8,16] beneath the south margin of the Central Iranian Block during the Middle Triassic [1] and/or the Upper Triassic [17], the Sanandaj-Sirjan zone (the active continental margin of Central Iranian Block) behaved as an active zone, supported by the presence of Mesozoic magmatic arc. Large transcurrent movements, as a result of oblique subduction, are the main mechanism for opening of the Nain-Baft Trantensional back-arc basin during middle to upper Cretaceous. Closure of this basin has been taken place probably during the lower Paleocene. This age is consistent with the sedimentary gap in the Nain-Dehshir ophiolites, picked up by the basal conglomerates with ophiolite fragments. Then transgressive shallow water sediments rest unconformably over the late Cretaceous pelagic rocks in middle Paleocene to lower Eocene (with basal conglomerates). The basin was again tectonically disrupted during middle Eocene to lower Oligocene, permitted the sedimentation of conglomerate, sandstone and greywacke of Akhore formation.

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