Asian J. Exp. Sci., Vol. 33, No. 2, 2019; 27-33

Online available on :
www.ajesjournal.com, ISSSN : 0971-5444

Geodynamic Evolution of Noorabad Ophiolites in Supra Subduction Zone of the Neo-Tethys Ocean (West Iran)

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Received: February 19, 2019; Revised: March 02, 2019; Accepted: April 09, 2019

Abstract : Zagros ophiolite belt in Iran, is a part of the Eastern Mediterranean belt ophiolite. This belt is divided into two groups: outer and inner Zagros ophiolites that ophiolites around central Iran are inner belt ophiolites and outer ophiolites include the Kermanshah, Neyriz and Hajiabad ophiolites. The Noorabad ophiolite is part of Kermanshah ophiolites. The rocks of this ophiolite are including peridotite, serpentinite, pegmatite gabbro, layered gabbro, isotropic gabbro, sheeted dike complexes, pillow basalts, andesite lavas and sedimentary rocks (radiolarite and late Cretaceous pelagic limestone). Based on geochemical studies the rocks of this ophiolitic complex have tholeiite and calcalalkine magmas signatures and formation in Suprasubduction zone environment. The Noorabad ophiolite represents the Neo- Tethyan oceanic lithosphere which originally existed between the Arabian-Iranian bloks that in Miocene emplaced.

Keyword: Zagros, Noorabad ophiolite, Suprasubductionzone, Neo- Tethyan ocean.

Introduction

Zagros ophiolite belt in Iran, is a part of the Eastern Mediterranean belt ophiolite, that have characteristics of ophiolites that associated with Supra Subduction Zone (SSZ), which have been investigated by researchers (Fig. 1) (ShafaiiMoghadam and Stern, 2011; Dilek *et al*., 2007; Parlak *et al*., 2006; Malpas *et al*., 2003; Hassanipak and Ghazi,2000; Arvin, 1990; Robinson and Malpas, 1990; Hebert *et al*., 1989; Pearce *et al*., 1983 ; Kiani, 2011 ; Kiani *et al*., 2015 ; Tahmasebi *et al*., 2016; Shafaii Moghadam *et al*, 2012).

This belt is divided into two groups: outer and inner Zagros ophiolites. Ophiolites around central Iran are inner belt ophiolites. The outer ophiolites include the Kermanshah, Neyriz and Hajiabad ophiolites (Shafaii Moghadam and Stern, 2011) with NW- SE trend are part of the 3,000-kilometer ophiolite belt that distributed from Cyprus to Oman (Dilek and Delaloy, 1992). The Kermanshah ophiolite as part of this ophiolite belt with 230 km long and 30-60 km wide (Fig. 2) in the west of Iran is part of the Neo-Tethys oceanic crust, that has been obducted on the margin of the Iran plate (Kiani, 2011). The Noorabad ophiolite is part of Kermanshah ophiolites in NW of Lorestan province, west of Iran. In this study, we try to investigate field geology, Mineralogy and geodynamic evolution of Noorabad ophiolite as the southern part of Kermanshah ophiolite.

2-Regional Geology

The Noorabad ophiolite complex with NW-SE trending is located in the SSW of the main Zagros thrust fault within the high zagros zone. The lithological sequence of these ophiolites zone from west to east including: Kermanshah radiolarites, Bisotun limestone and late cretaceous Kermanshah ophiolites. The Noorabad ophiolites contain some components of complete ophiolitic sequence including peridotite, serpentinite, pegmatite gabbro, layered gabbro, isotropic gabbro, sheeted dike complexes, pillow basalts, andesite lavas and sedimentary rocks (radiolarite and late cretaceous pelagic limestone) (Fig. 2 and Fig. 3). This ophiolite complex covers ~ 2400 km2 areas and is bounded to the north east by Sanandaj-Sirjan metamorphic rocks and to the SW by the Biston limestone, Kermanshah radiolarite and sedimentary rocks of folded and trusteed Zagros zone.

Petrographic and Mineralogical Studies

1-Peridotite

The peridotite unit rocks are the most altered part of Noorabad ophiolite that are including dunite, harzburgite and lherzolite. These rocks be seen form many large and small mass of green to gray. The minerals of these rocks are consist olivine, clinopyroxene, orthopyroxene and chrome-spinel that have mesh and granular texture that altered to serpentine minerals and iron-oxid.

2-Gabbro

These rocks are located in 15 kilometers north-west of the Noorabad city and are as large and small masses which have space 40 square kilometers. The rocks this unit is consists of troctolite, olivine gabbro and layered gabbros. The minerals of gabbros are including olivine, plagioclase, clinopyroxene and opaque mineral that altered to serpentine, amphibole, sericite and iron oxides. The segabbros have granular, poikilitic and cumulative textures.

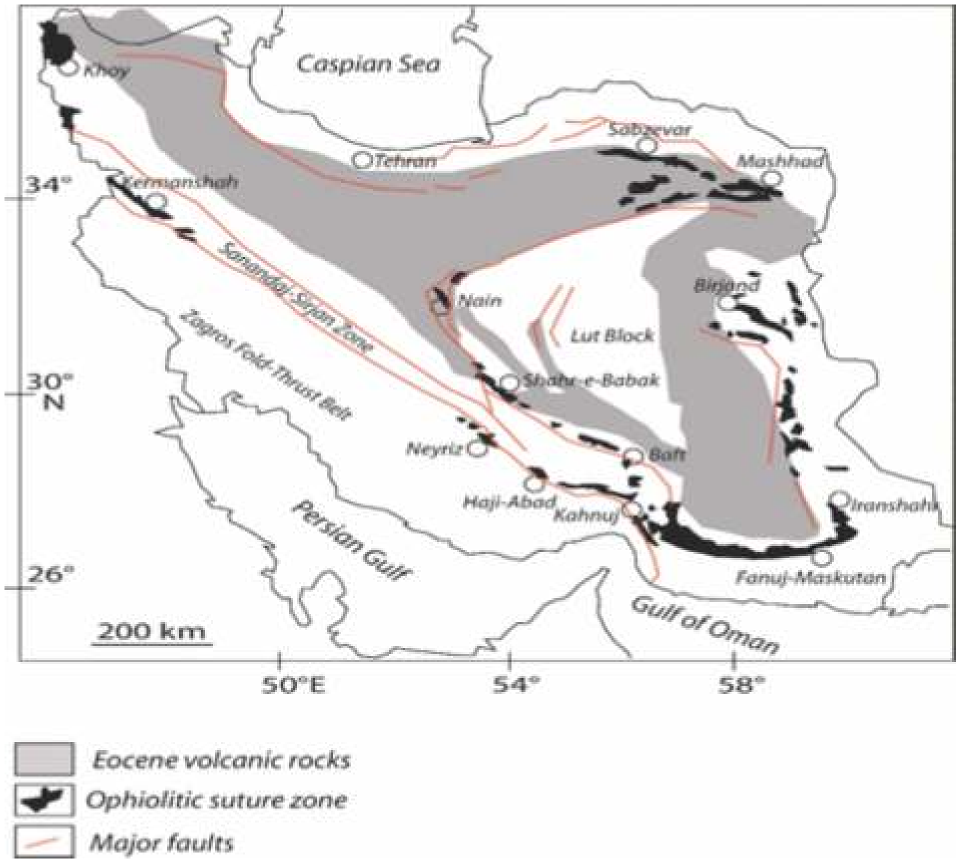

Fig.1. Map showing locations of major Iranian ophiolites (modified after Stocklin, 1968).

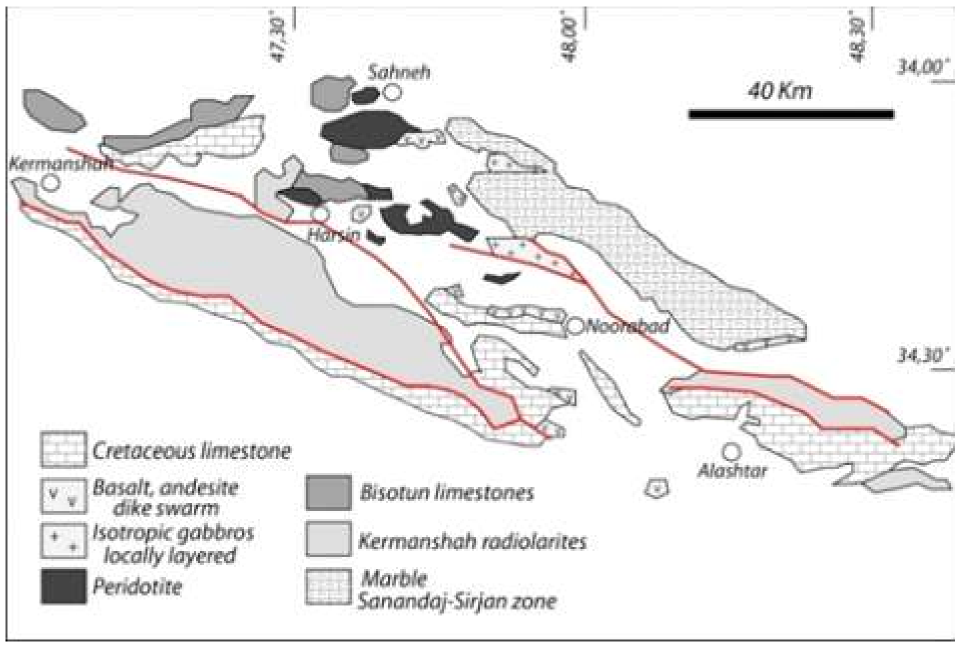

Fig. 2. Simplified geological map of Kermanshah ophiolites in the Noorabad region.

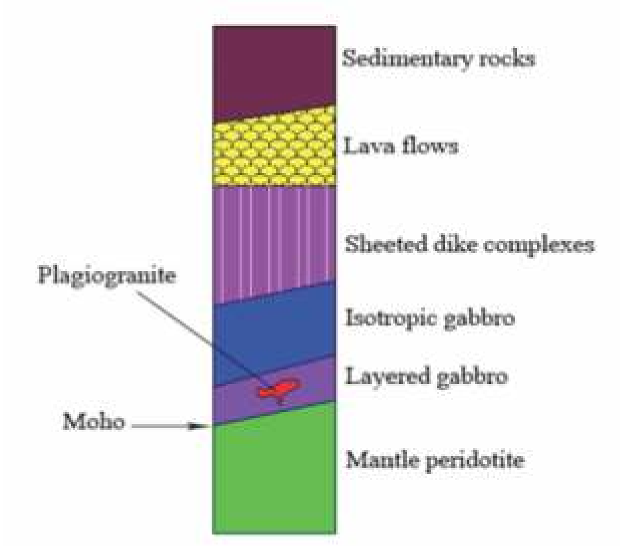

Fig. 3. Simplified stratigraphic column displaying idealized internal lithologic successions in the Noorabad ophiolite.

3-Plagiogranite

Plagiogranite unit of the study area is located in the northwest of the city Noorabad that is as a small white mass that has boundary fault with layered gabbros. The minerals in these rocks are consisted plagioclase, amphibole and quartz that have granular textures and their plagioclase altered to sericite and epidotiteþ.

4-Diabase dikes

Diabase dikes have been extensive but scattered and have green to brown colors that have plagioclase, clinopyroxene and opaque mineral. In these rocks, secondary mineral are included chlorite, zeolite, prehnite, iron oxides and sericite that rocks fractures and spaces are filled within minerals. These rocks have doleritic, intergranular and poikilitic texture.

5-Basaltic lava

The basaltic lava of this ophiolite divided into two types : (1) pillow lava (2) spilitic basalts. The pillow lavas have microvesicles that are filled with chlorite; carbonate and opaque minerals that located in a groundmass of plagioclase and clinopyroxene microlites. The spilitic basalts have plagioclase, clinopyroxene and minor opaque minerals (titaniferous minerals) that have intersertal texture. The clinopyroxenes of these rocks are uralitized and plagioclases altered into sericiteþ.

6-Andesite

The andesites of Noorabad ophiolite in hand specimen and thin section have phenocrysts of plagioclase in a groundmass of clinopyroxene and amphibole minerals. In these rocks, the primary minerals (plagioclase and pyroxene) of rocks altered to secondary minerals (chlorite, sericite, quartz, zeolite, andþ Fe-Oxide).The micro vesicles of these rocks are filled with secondary minerals consist of sericite, quartz, zeolite, chlorite and opaque mineralsþ. The plagioclases are euhedral to subhedral that shows evidence of fracture and breakage. These rocks have glomeroporphyritic and porphyritic texture. The opaque minerals in these rocks are consist of chalcopyrite, bornite, malachite, azurite, and Fe-oxide.

7-Radiolarites

This radiolarite unit has the maximum volume of the rocks of the Noorabad ophiolitic complex and has expanded from east of Noorabad to Kermanshah that has green to reddish brown colors. In some places in the rocks occurs Mn mineralization as veins and masses.

Geochemistry

In order to nomenclature and classification of studied volcanic rock the Nb/Y versus Zr/TiO2 diagram (Winchester and Floyd, 1977) were used, and all samples fall in the andesite-basalt, andesite, and rhyodacite- dacite fields (Fig. 4). In the Th/Yb versus Ta/Yb binary diagram (Pearce, 1983) studied samples plot in the subduction zone basalts (Fig. 5). The Th/Yb ratio in this diagram is a good indicator for the separation of Samples associated with subduction zone, from other environments, because the increase in this ratio and higher location of the samples than mantel array, (N-MORB-OIB) is related to addition fluid phase, due subducted slab in generated magmas at subduction zone. Also, on the Th/Yb versus La/Yb discriminate diagram (Condie, 1989)þ is used to distinguish the different volcanic arc, Noorabad volcanic rocks plot in the fields for islands arc within ocean basalts (Fig. 6).

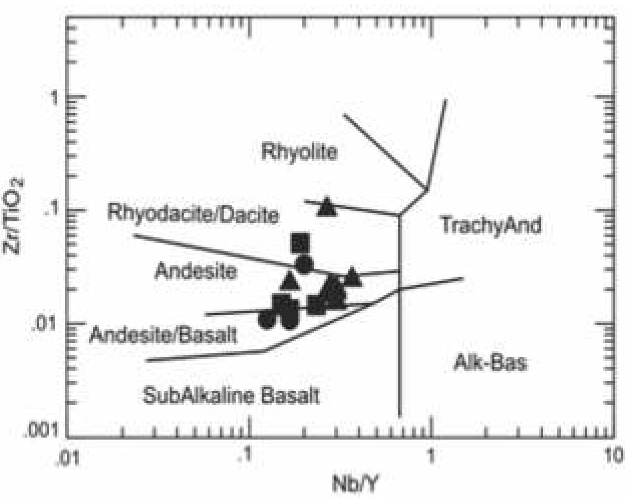

Fig. 4. Nb/Y versus Zr/TiO2 binary diagram for classification studied volcanic rocks (the studied samples shown with triangle for andesite, square for dikes and circle for basalts).

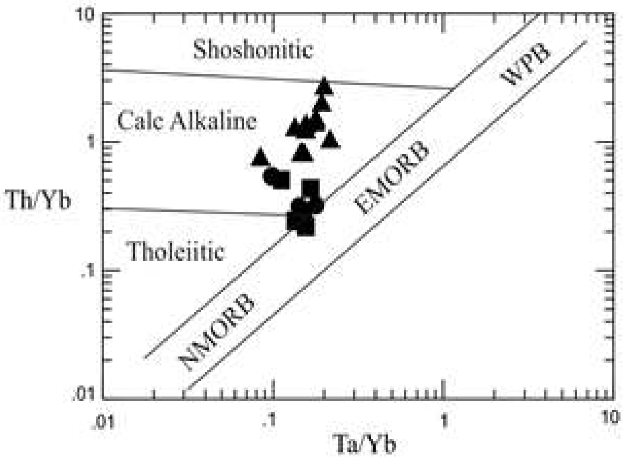

Fig. 5. The plotting of Th/Yb versus Ta/Yb diagram (Pearce, 1983) indicate a subduction zone tectonic setting which enriched by subducted fluids for studied samples. (Symbols as in Fig. 4).

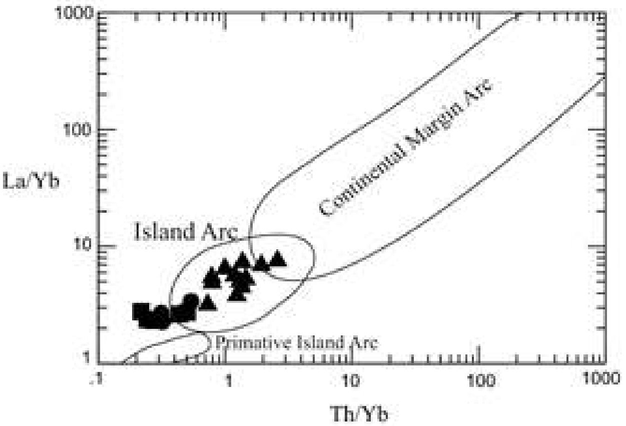

Fig. 6. Plot of Th/Yb versus La/Yb binary diagram (Condie.,1989) for studied volcanic rocks. All samples fall in the field of island arc fields. (Samples as in Fig. 4).

Discussion

Based on geochemical studies the rocks of Noorabad ophiolite have tholeiite and calc-alkaline magmas signaturesþ and also the plotted rock samples in different geochemical discrimination diagrams occur in island arc basalt (IAB) field. These patterns suggest that these rocks formed in intra oceanic subduction zone.These geochemical characteristics along with a comparison with other ophiolitic volcanic rocks in the east of Mediterranean reveal a subduction zone environment for the genesis of the volcanic rocks of the Noorabad ophiolite (Kiani, 2011; Kiani *et al*., 2015; Tahmasebi *et al*., 2015).

Several tectonic events have been reported by researchers for Ocean Neotethys (Berberian and King, 1981; Desmons and Beccaluva, 1983; Dercourt *et al*., 1986; Lippard *et al*., 1986; Glennie, 2000; Stampfli *et al*., 2001; Golonka, 2004; Agard *et al*., 2005; Robertson, 2007; Ghasemi and Talbot, 2005; Mohajjel *et al*., 2003) Which are essentially similar, but has different times (Allahyari *et al*., 2010) According to Mohajjel *et al*. (2003) evolution tectonic and genesis of Neo-Tethys Ocean was conducted in four stages:

1. Neo-Tethys formation in Triassic; 2. Neo-Tethyan oceanic crust subduction along the northeast margin during the Jurassic-Miocene; 3. ophioliteobduction along the northeast margin of the Arabian Plate; in the Cretaceous, 4. The collision Arabian Plate northeast margins with central Iran during the Miocene.

According to Stampfli *et al*. (2001) and Ghasemi and Talbot, (2005) Neo-Tethys Ocean opening occurred Permian time but some investigators (Lippard *et al*., 1986; Mohajjel *et al*., 2003; Agard *et al*., 2005; Allahyari *et al*., 2010) believe that this opening has occurred during the Triassic (Fig. 7-a). According to some authors, Neotethys lithosphere in the early Jurassic (Dercourt *et al*., 1986) or the Middle Jurassic (Agard *et al*., 2005) has subduction beneath the Iran margin. According to the ages determination carried out on granitoid plutonsþ وBoroujerd (Ahmadi Khalaji *et al*., 2007), Hamadan (Shabazi *et al*., 2010) and Aligoudarz (Esna-Ashari *et al*., 2012) the formation of this plutons belongs to Middle Jurassic age, then can be said the Neo-Tethys oceanic crust has subducted beneath the Iran margin at late Triassic - early Jurassic (compression phase of early Cimmerian) (Fig. 7-b), And by melting the oceanic crust, mentioned granitoid plutons are formed and then emplacement in Sanandaj- Sirjan Zone (Fig. 7-c). Dercourt *et al*. (1986) believe that in the time of subduction of oceanic crust under Iran, mid-oceanic ridge spreading zone is still present near the margin of the Arabian block.þ Agard *et al*. (2005) and Dercourt *et al*. (1986) suggested that Neo -Tethys ocean expansion like Iran and Oman ophiolite (Delaloye and Desmons, 1980; Knipper *et al*., 1986) have continued until late Cretaceous. Desmons and Beccaluva (1983) and Dercourt *et al*. (1986) believing that the subduction zone within the Neo-Tethys Ocean at Late Cretaceous is located near the Arabian block margin but Ghasemi and Talbot (2005) know this subduction as belonging to the Cretaceous but Agard *et al*. (2005) suggest that subduction within oceanic occurred in the early Cretaceous. Due to the evidence of volcanic, availableþ unconformity and located of limestone units Albian · Cenomanian age (Shahidi and Nazari, 1997) on the south-Noorabad Andesit, probably intraplate subduction occurred the late Jurassic (late Cimmerian) (Fig.7-d). Berberian and King (1981) suggest that Andes magmatism at Iran margin (Sanandaj - Sirjan zone) occurred at this time (Fig. 7-d).

There is a consensus about Arabian block margin collision with intra ocean arc, and all previous researchers have attributed this collision to the late Cretaceous (Laramide phase) (Fig. 7-e). At this time Urmia· daughter zone plutons, are emplacement due to more subduction of Neo-Tethyan oceanic crust beneath the Iran margin, but ShafaiiMoghadam *et al*. (2012) believed Magmatism (intrusive and volcanic rocks) in this zone belong to the Eocene · Miocene, that occurred after the closure of Naein-Baft ocean, and occurred due to Neo-Tethyan oceanic crust subducting under Iran (Fig. 7-e). Given that peridotite plutons at Aleshtar- Kermanshah axis ophiolites Covered by Oligo-Miocene pelagic limestones belong to warm and marginal sea (Kiani, 2011), can say that there has been no collision between Iran and Arabian block, during the

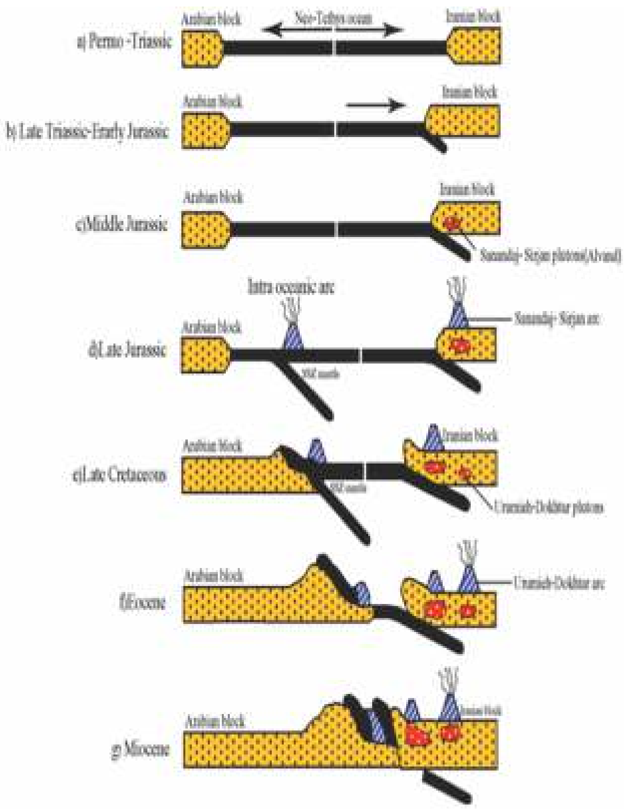

Fig.7. Tectono · magmatic schematic model of Noorabad ophiolite and surrounding areas. a) Opening during the Triassic, b) The late Triassic to early Jurassic subduction , c) Subduction of oceanic crust under Iran and mid-oceanic ridge extend areas, d) intra oceanic Subduction in the Late Jurassic, e) Urmia · daughter zone plutons as a result of Neo-Tethyan oceanic crust subducting under Iran, f) Peak magmatism activity (volcanic · plutonic) of Urmia-Dokhtar zone , g) Start time of collision between Arabia and Iran in Oligocene.

Eocene · Miocene.þ At this time magmatic activity (plutonic · volcanic) reached its peak at Urmia- Dokhtar zone, and granitic pluton such as Marvak (north Doroud) been emplacement in Sanandaj · Sirjan (Kiani, 2011) (Fig.7-f). Some researchers (Ghasemi and Talbot, 2005) considered that the collision between Iran and Arabian is belonging to the middle Eocene, but Agard *et al* (2005) attributed the beginning of the collision the Oligocene that continued to Pliocene. Mohajjel *et al*. (2003) believe that this collision is belonging to the Miocene, and Allahyari *et al*. (2010) suggest that collision started at Oligocene that continues to the present (Fig.7g).

In general determined, as the diagrams of the chondrite-normalized REE and trace elements is normalized to the primitive mantle, volcanic rocks of Noorabad ophiolite, show Calc-alkaline characteristics by depletion of HFSE and enrichment of LREE and LILE. These characteristics are Similar to another Tethyan ophiolite that outcrops along the Bitlis- Zagros Suture Zone, and their formation is associated with subduction zones. Kermanshah ophiolite age (similar to another ophiolite East Mediterranean - Zagros-Oman) is considered 86.3 µ 7.8 and 81.4 µ 3.8 Ma by the K-Ar method (Delaloye and Desmons, 1980; Braud, 1970; Hassanipak and Ghazi, 1999). Geochemical characteristics of volcanic sequence in Kermanshah ophiolite complex is considered, similar to series ofþ island arc tholeiites and oceanic islands Basalt (OIB), with smaller amounts lava similar to MORB (Desmons and Beccaluva, 1983; Hassanipak and Ghazi, 1999). It seems that alkaline lavas type that mentioned by Ghazi and Hassanipak (1999) in Kermanshah ophiolite complex, not associated with the ophiolite complex, and related to the primary rift in the Permian, and has been sampled from basaltic sequence between Bisoton lime stones. This alkaline basalt type is also seen in Neyriz of Iran and Havasina of Oman series (Triassic to Cretaceous) and related to Gondwana rifting in the early stages of Neotethys ocean formation. ShafaiiMoghadam and Stern (2011) studies, suggests that pillow basalt and dikes in Kermanshah ophiolite complex sheeted dikes has Characteristics of island arc tholeitic and calc-alkaline, and confirmed the results of this study.

Conclusions

The rocks of peridotite, serpentinite, pegmatite gabbro, layered gabbro, isotropic gabbro, sheeted dike complexes, pillow basalts, andesite lavas and sedimentary rocks (radiolarite and late cretaceous pelagic limestone) have formed the Noorabad ophiolite, as part of Kermanshah ophiolites. Our studies showed that the rocks of Noorabad ophiolite have tholeiite and calc-alkaline magmas signaturesand also the plotted rock samples in different geochemical discrimination diagrams occur in island arc basalt (IAB) field. These patterns suggest that these rocks formed in intra oceanic subduction zone. In general, as specified by geochemical studies Noorabad ophiolite have characteristics that are similar to other Tethyan ophiolite that outcrops along the Bitlis-Zagros Suture Zone, and their formation is associated with intra oceanic arc subduction zones. According to previous studies about tectonic events for Neotethys Ocean, and our detailed studies Geodynamic evolution of Noorabadophiolites in Supra Subduction Zone of the Neo-Tethys Ocean (west Iran) includes: A) Opening during the Triassic, B) The late Triassic to early Jurassic subduction, C) Subduction of oceanic crust under Iran and mid-oceanic ridge extend areas, D) Intra oceanic Subduction in the Late Jurassic, E) Urmia · daughter zone plutons as a result of Neo-Tethyan oceanic crust subducting under Ira, F) Peak magmatism activity (volcanic · plutonic) of Urmia -Dokhtar zone, G) Start time of collision between Arabia and Iran in Oligocene.

References

Allahyari K. Saccan E. Pourmoafi M. Beccaluva L. and Masoudi F. (2010): Petrology of mantle peridotites and intrusive mafic rocks from the Kermanshah Ophiolitic Complex (Zagros Belt, Iran): implications for the geodynamic evolution of the Neo-Tethyan oceanic branch between Arabia and Iran. Ofioliti, 35(2):71-90, doi: 10.4454/ofioliti.v35i2.387.

Agard P. Omrani L. Jolivet L. and Mouthereau F. (2005): Convergence history across Zagros (Iran): constraints from collisional and earlier deformation. International Journal of Earth Sciences (GeologischeRundschau), 94: 401· 419.

Ahmadi Khalaji A. Esmaeily D. Valizadeh M.V. and Rahimpour-Bonab H. (2007): Petrology and geochemistry of the granitoid complex of Boroujerd, Sanandaj-Sirjan Zone, Western Iran. Journal of Asian Earth Sciences, 29:859-877.doi: 10.1016/j.jseaes.2006.06.005.

Arvin M. (1990): Petrology and geochemistry of ophiolites and associated rocks from the Zagros suture, Neyriz, Iran. In: Malpas, J. Moores E.M. Panayiotou A. Xenophontos C. (Eds.), Ophiolites, Oceanic Crustal Analogues. Proceedings of the Symposium „Troodos 1987‰The Geological Survey Department, Nicosia, Cyprus:351· 365.

Berberian M. and King G.C.P. (1981): Towards a paleogeography and tectonic evolution of Iran. Canadian Journal of Earth Sciences, 18: 210· 265.

Braud J. (1970): Les formations du Zagros dans la region de Kermanshah (Iran) etleurs rapports structuraux. ComptesRendusl'Academie des Sciences 271: 1241· 4.

Braud, J. (1978): Geological Map of Kermanshah, 1/250000 scale. Tehran: Geological Survey of Iran.

Condie K. C. (1989): Geochemical changes in basalts and andesites across the Archean-Proterozoic boundary: identification and significance. Lithos 23: 1-18.

Delaloye M. and desmon S.J. (1980): Ophiolites and mélange terranes in Iran: a geochronological study and its paleotectonic implications. Tectonophysics 68, 83· 111.

Dercourt J. Zonenshian L.P. Ricou L.E. Kazmin V.G. Le Pichon X. *et al*., (1986): Geological evolution of the Tethys Belt from the Atlantic to the Pamirs since the Lias. Tectonophysics, 123, 241-315, doi: 10.1016/0040-1951(86)90199-X.

Desmons J. and Beccaluva L. (1983): Mid-ocean ridge and island arc affinities in ophiolites from Iran: palaeographic implications. Chemical Geology, 39:39· 63, doi: 10.1016/0009-2541(83)90071-2.

Dilek Y. and Delaloye M. (1992): Structure of the Kizildagophiolite, a slow-spread Cretaceous ridge segment north of the Arabian promontory. Geology 20, 19-22.

Dilek Y. Furnes and H. Shallo M. (2007): Suprasubduction zone ophiolite formation along the periphery of Mesozoic Gondwana. Journal of Gondwana Research 11,453-475.

Esna-Ashari A. Tiepolo M. Valizadeh M.V., Hassanzadeh, J. and Sepahi, A.A., 2012. Geochemistry and zircon U-Pb geochronology of Aligoodarzgranitoid complex, Sanandaj-Sirjan Zone. Iran. Journal of Asian earth Science, 43:11-22.

Ghasemi A. and Talbot C.J. (2005): A new tectonic scenario for the Sanandaj · Sirjan Zone (Iran). Journal of Asian Earth Sciences, 24:1· 11, doi: 10.1016/j.jseaes.2005.01.003.

Glennie K.W. (2000): Cretaceous tectonic evolution of Arabia's eastern plate margin: a tale of two oceans, In: A.S. Alsharan and R.W. Scott (Eds.), Middle East models of Jurassic/Cretaceous carbonate systems. SEPM, Geological Society of London Special Publication, 69: 9-20.

Golonka J. (2004): Plate tectonic evolution of the southern margin of Eurasia in the Mesozoic and Cenozoic. Tectonophysics, 381:235-273, doi: 10.1016/j.tecto.2002.06.004.

Hassanipak A.A. and Ghazi A.M. (2000): Petrology, geochemistry and tectonic setting of the Khoyophiolite, northwest Iran: implications for Tethyan tectonics. Journal of Asian Earth Sciences, 18:109· 121.

Hébert R. Serri G. and Hekinian R. (1989): Mineral chemistry of ultramafic tectonites and ultramafic to gabbroic cumulates from the major oceanic basins and Northern Apennine ophiolites (Italy): a comparison. Chemical Geology, 77:183· 207.

Kiani M. (2011): Geochemistry, economic geology and petrogenesis of the ophiolite complex in the Alashtar-Kermanshah axis. M.Sc thesis, Islamic Azad University, Khorramabad Branch, Iran (in Persian).

Kiani M. Ahmadi-Khalaji A. Kamali Z. and ShafaiiMoghadam H. (2015): Geochemistry of diabasic dikes and andesitic-basaltic lavas in Noorabad-Kermanshah ophiolite. Journal of Tethys: 3(1) 1· 15.

Kiani M. Panahi A. Shabani Z. Moridi and M. M Bijani M. H. (2014): Geology, Petrology and Geochemical Dispersion of Elements in Noorabad Ophiolite (Northwest Lorestan), Iran. Journal of Academic and Applied Studies (Special Issue on Applied Sciences): 4: 37· 50.

Knipper A. Ricou L. E. and Dercourt J. (1986): Ophiolites as indicators of the geodynamic evolution of the Tethyan Ocean. Tectonophysics, 123:213-240, doi: 10.1016/0040-1951(86)90198-8.

Lippard S.J. Shelton A.W. and Gass I.G. (1986): The Ophiolite of Northern Oman. GeolgicalSoeciety London Mem, 11: 178.

Malpas J.and Zhou M.-F. Robinson P.T. Reynolds P.H. (2003): Geochemical and geochronological constraints on the origin and emplacement of the YarlungZangboophiolites, Southern Tibet. In: Dilek, Y. and Robinson P.T. (Eds.), Ophiolite s in Earth History. Geological Society of London Special Publication, 218: 191· 206.

Mohajjel M. Fergusson C.L. and Sahandi M.R. (2003): Cretaceous · Tertiaryconvergence and continental collision, Sanandaj-Sirjan Zone, Western Iran. Journal of Asian Earth Sciences, 21:397 · 412, doi: 10.1016/S1367-9120(02)00035-4.

Parlak O. Hoeck V. Kozlu H. Delaloye M. (2006): Oceanic crust generation in an island arc tectonic setting, SE Anatolian Orogenic Belt (Turkey). Geological Magazine 141: 583· 603.

Pearce J.A. (1983): Role of sub-continental lithosphere in magma genesis at active continental margins. In: Hawkesworth C.J. Nurry M.L. (Eds.), Continental Basalts and Mantle Xenoliths. Shiva, Nantwich: 230-249.

Robertson A.H.F. (2007): Overview of tectonic settings related to the rifting and opening of Mesozoic ocean basins in the Eastern Tethys: Oman, Himalayas and Eastern Mediterranean regions. In Imaging, Mapping and Modeling Continental Lithosphere Extension and Breakup (eds G. D. Karner G. Manatschal & L. M. Pinheiro). Geological Society of London, Special Publication, no 282: 325-388, doi: 10.1144/SP282.15.

Robinson P.T. and Malpas J. (1990): The Troodos ophiolite of Cyprus: new perspectives on its origin and emplacement. In: Malpas J. Moores E.M. Panayiotou A. Xenophontos C. (Eds.) Ophiolites, Oceanic Crustal Analogues. Proceedings of the Symposium „Troodos 1987‰ The Geological Survey Department, Nicosia, Cyprus:13· 26.

ShafaiiMoghadam H. and Stern R. J. (2011): Geodynamic evolution of Upper Cretaceous Zagros ophiolite s: formation of oceanic lithosphere above a nascent subduction zone. Geological Magazine, 148:762· 801, doi: 10.1017/S0016756811000410.

ShafaiiMoghadam H. Stern R. J. Kimura J.I. Hirahara Y. Senda R. and Miyazaki T. (2012): Hf-Nd Isotopic Constraints on the Origins of Zagros Ophiolite s. The Island Arc, 21:202-214. doi: 10.1111/j.1440-1738.2012.00815.x.

Shahbazi H. Siebel W. Pourmoafee M. Ghorbani M. Sepahi A.A. Shang C.K. and VousoughiAbedini M. (2010): Geochemistry and U· Pb zircon geochronology of the Alvand plutonic complex in Sanandaj· Sirjan Zone (Iran): New evidence for Jurassic magmatism. Journal of Asian Earth Sciences, 39:668· 683, doi: 10.1016/j.jseaes.2010.04.014.

Shahidi M. and Nazari H. (1997): Geological map of Harsin, 1/100.000 scale. Geological survey of Iran.

Stampfli G. Mosar J. Faure P. Pillevuit A. and Vannay J.C. (2001): Permo-Mesozoic evolution of the western Tethys realm: the Neotethys East Mediterranean basin connection. In: P. Ziegler, W. Cacazza, A.H.F. Robertson and S. Crasquin-Soleau (Eds.), Peri-Tethyan rift/wrench basins and passive margins. Mem. Mus. Nat. Hist. Nat., Peri-Tethys Mem, 5:51-108.

Tahmasbi Z. Kiani M. and Ahmadi-Khalaji A. (2015): Petrology and Geochemistry of Diabasic Dikes and Andesitic-Basaltic Lavas in Noorabad-HarsinOphiolite, SE of Kermanshah, Iran. Journal of Earth Science, 27(6): 935· 944.

Winchester J.A. and Floyd P.A. (1977): geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology 20: 325 · 342.