Islamic Azad University
Mashhad Branch

Arfania / Iranian Journal of Earth Sciences 10 (2018) / 31-38

Role of supra-subduction zone ophiolites in the tectonic evolution of the southeastern Zagros Orogenic Belt, Iran

Ramin Arfania*[1]

1. Department of Geology, Faculty of Basic Science, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

Received 11 December 2016; accepted 7 September 2017

Abstract

Ophiolitic rocks in the southeastern part of the Zagros Orogenic Belt can be separated from southwest to northeast, into two groups: the Neyriz ophiolites and the Naien–Shahrebabak–Baft ophiolites. The southeast sector of Sanandaj-Sirjan was delimited by the two nearly synchronous ophiolitic belts in its southwestern and northeastern margins. In this study, new ophiolitic formation models were used to explain a viable geodynamic hypothesis on the development of the southeastern Zagros Orogenic Belt. Supra-subduction zone ophiolites have been of particular importance in the reconstruction of regional tectonic evolution and formed near a main subducting oceanic plate. The history of the southeastern Zagros Orogenic Belt is composed of development of two oceanic crusts, referred to as the Neo-Tethys 1 and Neo-Tethys 2. The process of reconstructing of the plate tectonic evolution of the southeastern Zagros Orogenic Belt was proposed on the basis of "Latest Cretaceous-Neogene collision" hypothesis. The supra-subduction zone ophiolites in the southeastern part of the Zagros Orogenic Belt can be classified into "pull related fore-arc Neyriz ophiolites" and "back-arc Naien-Baft ophiolites".

Keywords: *Ophiolite, Sanandaj-Sirjan, Supra-subduction zone, Zagros Orogenic Belt.*

1. Introduction

The Zagros Mountains is located within the Alpine-Himalaya Orogenic System and stretch in NW-SE direction for ca. 2000 km from the southeastern Turkey to the Bandar-Abas syntax in the south of Iran. Neotethyan ophiolites have an important role in the Alpine-Himalaya Orogenic System and indicate the exact location of sutures between continental blocks rifted from Gondwana, such as Arabian and Indian plates as well as the Iranian terranes. These ophiolites have been reviewed by multiple authors (e.g., Dilek and Furnes 2009; Topuz et al. 2013). The southeast of this orogenic belt was built by several stages of subduction, obduction and finally collision of the Arabian continental plate with the Iranian terranes specified as: Sanandaj-Sirjan and Central Iran - Micro-Continent (Golonka 2007; Ruban et al. 2007) (Fig 1a). The southeast sector of Sanandaj-Sirjan is the suspecting terrane that lying between the northeast margin of the Arabian Plate and the Central Iran Micro-Continent. It was delimited by two nearly synchronous ophiolitic belts in its southwestern and northeastern margins, named as Neyriz and Naien- Baft ophiolites respectively (Fig 1c). The hypotheses on the development of the southeastern Zagros Orogenic Belt and Iranian Neotethyan ophiolites (e.g., Nouri et al. 2016; Shafaii-Moghadam and Stern 2015) tried to explain how the ophiolitic belts formed approximately at the same time in southwest and northeast of the Sanandaj-Sirjan Zone, but any of them don't discuss geodynamic relationship between these. Here, we give answers to this query and reconstruct the plate tectonic evolution of the southeastern Zagros Orogenic Belt based on new ophiolitic models including formation of the oceanic lithospheres in forearc and back-arc basin settings and development of supra-subduction zone ophiolites.

----
*Corresponding author.
E-mail address (es): arfania@khuisf.ac.ir

2. Geological background

The southeastern Zagros Orogenic Belt consists of three parallel tectonic subdivisions, from northeast to soutwest (Alavi 1994): (1) Urumieh-Dokhtar Magmatic Assemblage; (2) Sanandaj–Sirjan Zone; (3) Zagros Fold-Thrust Belt (Fig 2).

The Urumieh-Dokhtar Magmatic Assemblage is an ensialic intrusive-extrusive complex, constructed by subduction of the Neo-Tethyan oceanic lithosphere underneath the Iranian terranes in a continental island-arc setting (Berberian et al. 1982; Shahabpour 2007). Although the magmatic activity has continued from Cretaceous to Recent, its highest activity peak occurred in Eocene time (Dimitrijevic 1973; Farhoudi 1978; Amidi et al. 1984). This magmatism was generally subduction-related calc-alkaline (Forster et al. 1972; Jung et al. 1976; Berberian et al. 1982; Ahmad and Posht-Kuhi 1993; Shahabpour 2007).

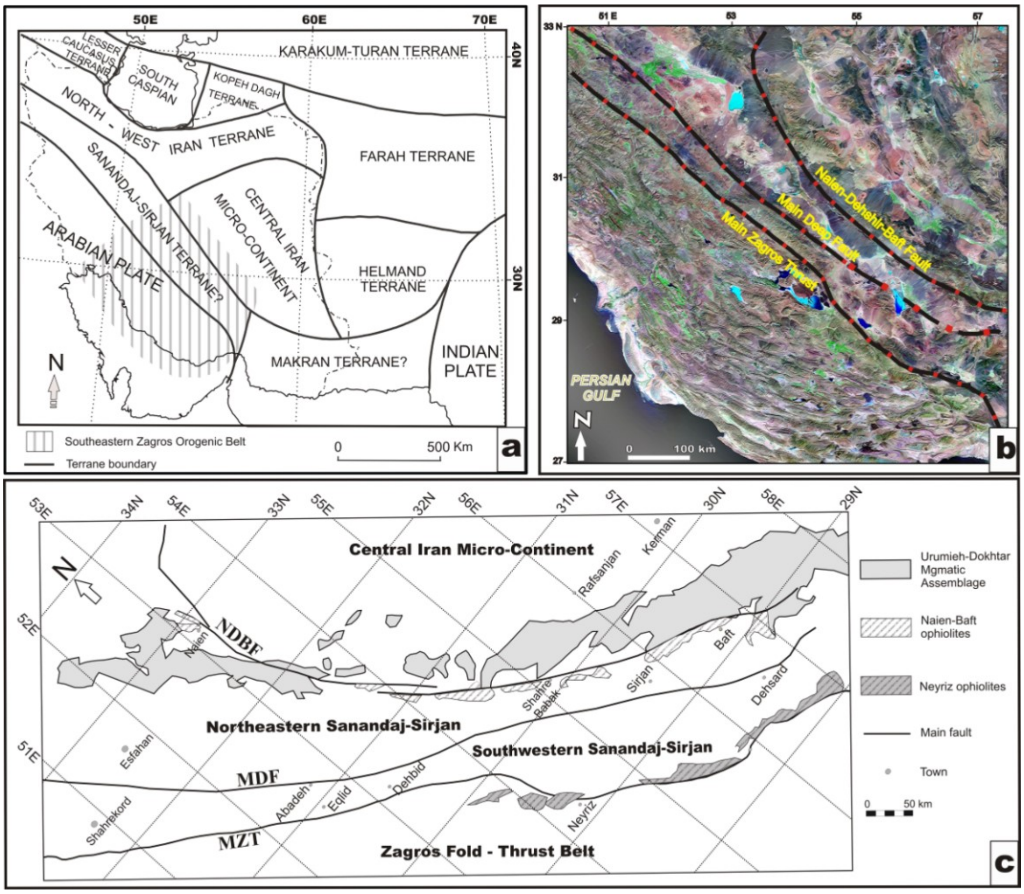

Fig 1. (a) The configuration of the present-day Iranian terranes including North-West Iran, Central Iran Micro-Continent, and Sanandaj-Sirjan. (Modified after Ruban et al. 2007). (b) Landsat TM view and major lithospheric faults across the southeastern Zagros Orogenic Belt. (c) Simplified structural map of the southeastern Zagros Orogenic Belt (Compiled from Shahabpour 2005; Taraz 1974). MZT, Main Zagros Thrust; MDF, Main Deep Fault; NDBF, Naien-Dehshir-Baft Fault. (Arfania and Shahriari 2009).

The southeastern Sanandaj–Sirjan is a sedimentary-metamorphic zone that is positioned between the Urumieh-Dokhtar Magmatic Assemblage and the Zagros Fold-Thrust Belt (Stöcklin, 1968; Ricou 1971). Taraz (1974) subdivided the southeastern Sanandaj–Sirjan zone into separate regions (Fig 1c): (1) a northeastern region (Esfahan-Sirjan Block) consisting of Paleozoic, Mesozoic and Cenozoic sedimentary rocks with typical Central Iranian stratigraphic features and (2) a southwestern region (Shahrekord-Dehsard Terrane), which is an intensively faulted zone consisting of high to medium-grade metamorphic rocks and Mesozoic metasedimentary layers with intercalations of intermediate volcanics. The boundary between the southwestern and the northeastern regions is a major fault that Taraz (1974) was first to name it as the Main Deep Fault (Fig 1b, c).

The Zagros Fold-Thrust Belt is resulted by total shortening of 65-78 km over the Zagros basin (Fig 2). The basin itself is characterized by a sequence of sedimentary rocks up to 12 km thick (Stöcklin 1968; Falcon 1974; Colman-Sadd 1978) including Paleozoic and Mesozoic passive margin sediments and Cenozoic synorogenic foreland strata that were deposited on the northeastern subsiding continental margin of the Arabian Plate. The Plio-Pleistocene conglomerates have unconformably been deposited on older formations throughout the Zagros Fold-Thrust Belt, implying that the main orogenic event occurred in the lower Pliocene (Stöcklin 1968, 1974; Berberian and King 1981; Şengör 1990; Hessami et al. 2001). The Plio-Pleistocene conglomerates filled the synclinal valleys of folds or larger-scale depressions caused by sever basement-involved deformation (Mouthereau et al. 2007). The Zagros Fold-Thrust Belt is bounded on the northeast by the Main Zagros Thrust.

3. Ophiolite concept

It is very important that the synchronous neighboring ophiolites consider as consequences of sinking of a cold, old and dense oceanic lithosphere which we name here as "main subducting plate". Mesozoic and Paleogene ophiolitic belt of the Zagros Orogenic Belt can be grouped by age and geological location into; Late Cretaceous Zagros outer belt ophiolites along the Main

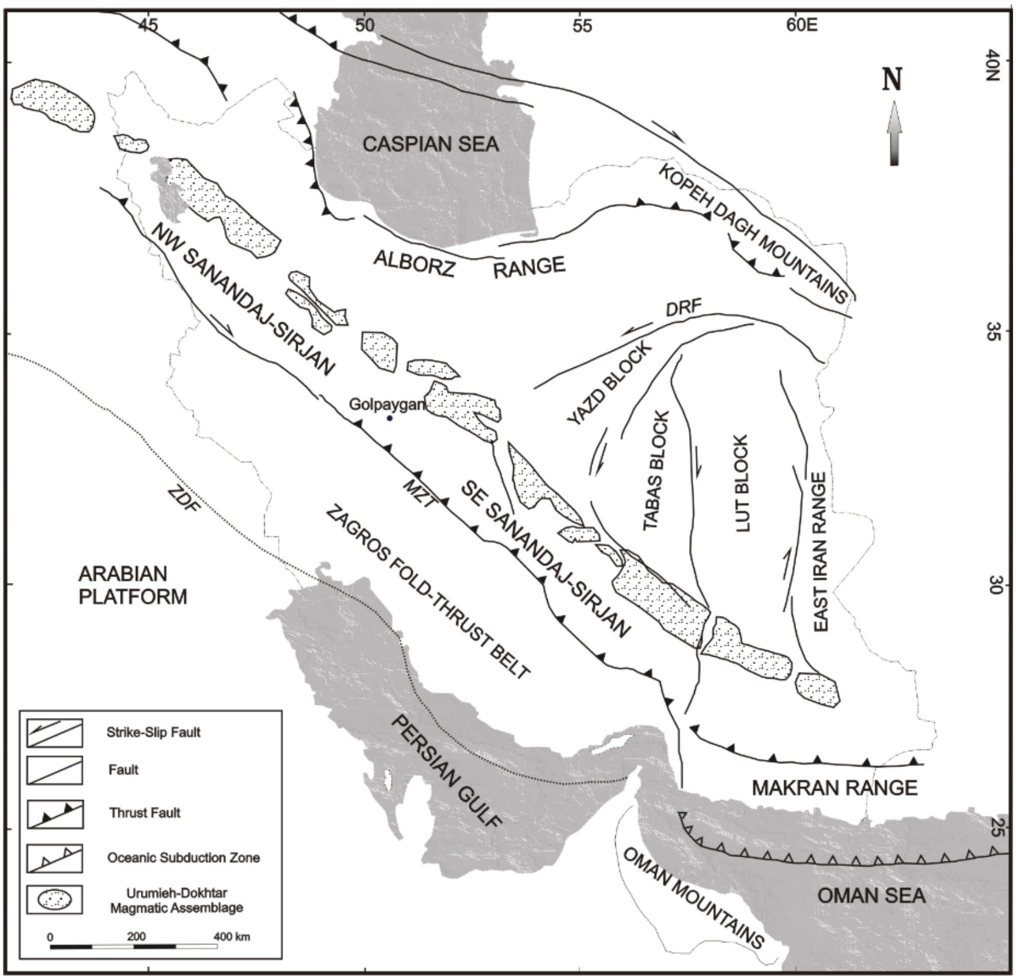

Fig 2. Simplified structural map of Iran (Compiled from Berberian 1976; Eftekharnejad 1981; Jackson and McKenzie 1984). Abbreviations: ZDF – Zagros Deformation Front; MZT – Main Zagros Thrust; MDF – Main Deep Fault; DRF - Darouneh Fault.

Zagros Thrust including Neyriz and Esfandagheh (Haji Abad) ophiolites; b) Late Cretaceous Zagros inner belt ophiolites including Naien, Dehshir, Shahr-e-Babak ophiolites along the southern periphery of the Central Iranian block (Shafaii-Moghadam and Stern 2015). As a geodynamic overview, "supra-subduction zone" ophiolites construct near the main subducting plate (Fig 3) and can be classified into two main groups:

- The back-arc ophiolites that form by tension over the margin of continent because of mantle dragging, trench suction and rapid extension of upper plate toward the inside the gap.
- The fore-arc basin ophiolites that can be classified into two subgroups according to the motion of the main subducting plate: (1) "Rollback related fore-arc ophiolites" that form owing to sinking of the main subducting plate beneath main subduction zone and influx of the asthenosphere into existing gap resulting from rollback of the oceanic lithosphere, (2) "Pull related fore-arc ophiolites" that form due to pull of the main subducting plate and influx of the asthenosphere into existing gap resulting from the extensional setting.

4. Zagros ophiolitic belts

Ophiolitic rocks in the southeastern Zagros Orogenic Belt can be separated, from the southwest to the northeast, into the Neyriz ophiolites and the Naien-Baft ophiolites (Fig 1c). Each of these is briefly described here below.

4.1. Neyriz ophiolites

The Neyriz ophiolitic rocks is a part of a 3000 km long belt, known as the Bitlis-Zagros-Oman Ophiolitic Belt (Ricou 1971; Gansser 1974; Stöcklin 1977; Coleman 1981; Stoneley 1990; Hassanipak et al. 2003). The mantle sequence contains depleted to impregnated harzburgites, layered leucogabbro, olivine-bearing melanogabbro and pyroxenite cumulate sills and lenses with screens of residual dunite, podiform chromitite, pyroxenitic sills and dikes, pegmatite gabbros, gabbroic

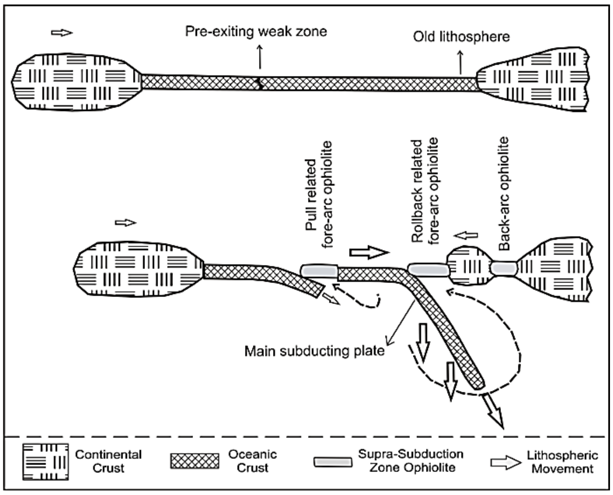

Fig 3. The Cartoon showing the oceanic lithospheres created in forearc and back-arc basin settings.

dikes/sills, isotropic melano- to leuco-gabbros and diabasic–basaltic–andesitic dikes (Shafaii-Moghadam and Stern 2015). The ophiolitic complex was obducted along the northeast margin of Afro-Arabian Plate in the Late Cretaceous (Stöcklin 1974; Ghasemi and Talbot 2006). The isotopic compositions, ophiolite tectonostratigraphy, and correlation of the $^{40}Ar/^{39}Ar$ cooling (plagiogranite) and deformation (amphibolite) ages, all suggest that the Neyriz ophiolites were formed in a supra-subduction zone and emplaced into an accretionary prism around 82–96 Ma (Babaie et al. 2006).

Chemical analysis on the volcanic-volcaniclastic sequence indicated that the magmatic rocks were related to marginal subduction zone. Sedimentological studies suggested that the overlying sedimentary sequence was deposited in a fore-arc marginal basin, over a NE-dipping subduction zone (Babaie et al. 2001, 2003, 2006). Extensive Late Jurassic and Cretaceous volcanic rocks (diabase and andesitic lavas) documented from the southern Eqlid (Fig 1c) (Berberian and King 1981) can be related to the fore-arc basin. The Neyriz ophiolites are clearly of supra-subduction zone "Fore-arc type" (Stern 2004). It is relatively easy to emplace the oceanic lithosphere of fore-arcs in this manner, because subduction of buoyant material leads to failure of the subduction zone and isostatic rebound of the buoyant material follows, with the ophiolites on top (Stern 2004).

4.2. Naien- Baft ophiolites

The Naien-Baft ophiolites (Fig 1c) are located along the Naien-Dehshir-Baft fault in the northern margin of the Esfahan-Sirjan Block. These have been dated as Late Cretaceous-Paleocene (Babaie et al. 2001). The crystallization age of the amphibole-bearing gabbros have been dated as Turonian (93 Ma), using K-Ar method (Shafaii-Moghadam et al. 2007); they are therefore just about the same age as ophiolites of the Neyriz ophiolites.

These ophiolites were emplaced during the end Cretaceous (Desmon and Beccaluva 1983) to Paleocene time (Lippard et al. 1986).

The Naien ophiolite includes a mafic and felsic sheeted dike complex with lava flows, Globotruncana-bearing Late Cretaceous pelagic limestones and unconformably a basal conglomerate over them (Shafaii-Moghadam and Stern 2015). Basaltic rocks from the Baft ophiolite mélange (Fig 1c) are transitional between island-arc tholeiite, mid-ocean ridge basalt, and within-plate basalts on a $MnO–TiO_2–P_2O_5$ discrimination diagram, suggesting a back-arc basin affinity (Shahabpour 2005). Furthermore, new geochemical facts show that mafic and more-evolved rocks in this belt tend towards island arc tholeiites, mid-oceanic ridge tholeiites and calc-alkaline magmatic rocks, indicating a supra-subduction setting for their formation (Shafaii-Moghadam et al. 2007). The Baft ophiolite is in fault or unconformable contact with Middle to Late Eocene sedimentary-volcanic sequences related to the Urumieh–Dokhtar arc (Shafaii-Moghadam and Stern 2015).

The Shahrebabak ophiolitic complex (Fig 1c) lies northeast of the Baft ophiolitic complex along the Naien-Baft ophiolites. The igneous rocks from the ophiolite mélange consist of lherzolite, harzburgite, dunite, serpentinite, pyroxenite, gabbro, diorite, and a volcanic sequence ranging from basaltic andesite to rhyodacite-rhyolite and trachyandesite. The extrusive rocks comprised from two discrete magmatic sources: the melt that produced the basaltic andesite and rhyodacite was generated in an island-arc environment, and the melt that initiated the trachyandesite was created in a within-plate setting (Ghazi and Hassanipak 1999; Hassanipak and Ghazi 2000).

As a result, The Naien-Baft ophiolitic rocks are seen to be of "back-arc type" of supra-subduction zone ophiolites.

5. Tectonic history of southeastern part of Zagros Orogenic Belt

Different hypotheses for the mechanisms of continental rifting, the starting of oceanic vs. continental subduction, and the initiation of continental collision in the southeastern part of Zagros Orogenic Belt have been suggested. Some of these are not fully consistent with new ophiolite concept (e.g. Alavi 1994, 2004).

The Zagros geodynamic hypotheses which are compatible with the new ophiolite concept can be categorized into two main groups in accordance with time of continental collision between the Arabian Plate and the Iranian terranes. In the first hypothesis, the continental collision considered to be occurred in the latest Cretaceous (e.g. Sheikholeslami 2008), whereas in the latter, it was proposed within the Neogene (e.g. Berberian 1983). There are some disharmonies between

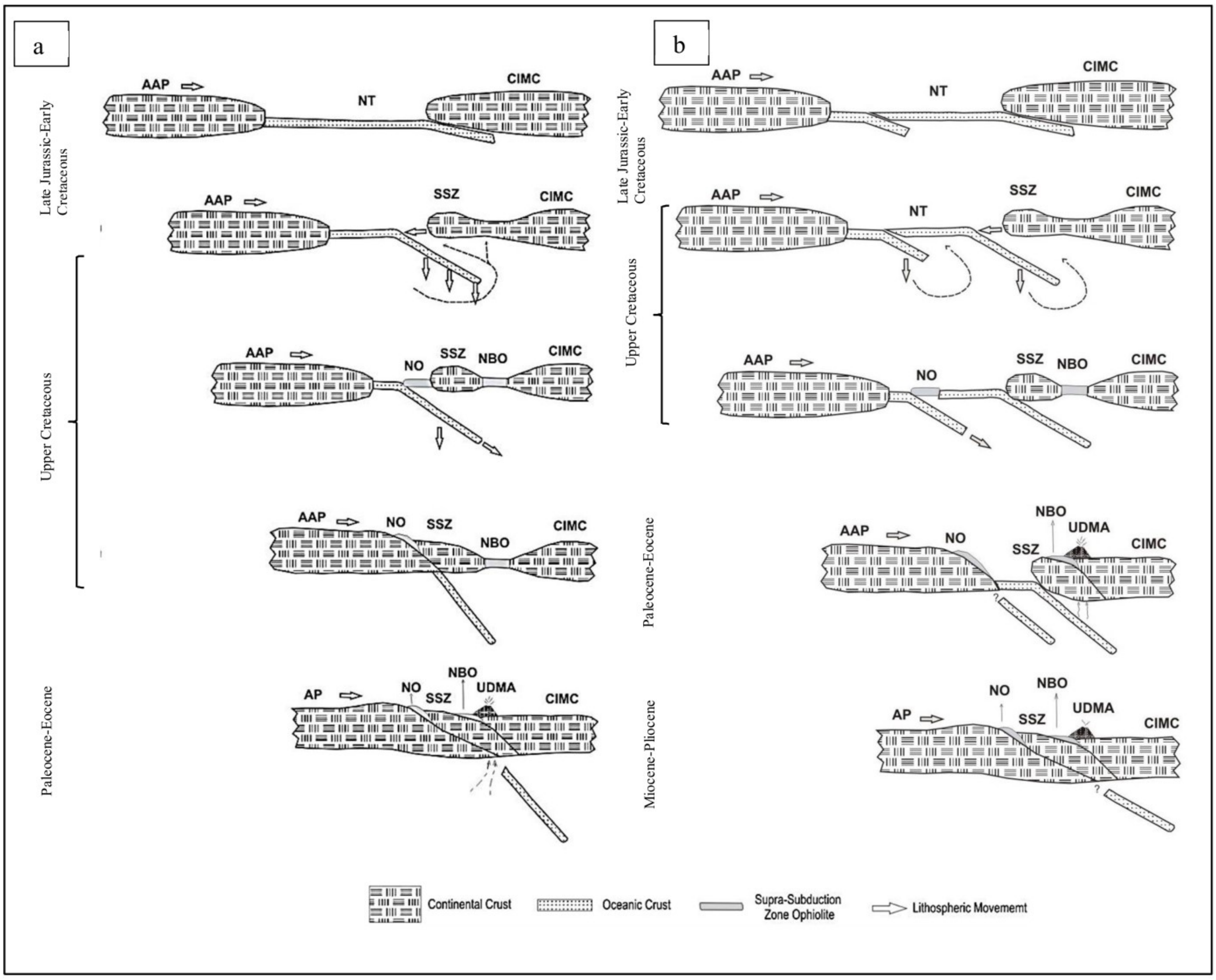

Fig 4. The series of sketches illustrating the tectonic evolution of the southeastern Zagros orogenic belt. (a) "Latest Cretaceous collision" hypothesis considers one subduction zone is located to the southwest of the Sanandaj–Sirjan Zone. (b) "Neogene collision" hypothesis considers two subduction zones are located to the southwest of the Sanandaj–Sirjan Zone. (c) "Latest Cretaceous-Neogene collision" hypothesis considers two belts of spreading oceanic crust as Neo-Tethys 1 and Neo-Tethys 2. AAP, Afro-Arabian Plate; NT1, Neo-Tethys 1; NT2, Neo-Tethys 2; CIMC, Central Iran Micro-Continent; NO, Neyriz ophiolites; NBO, Naien-Baft ophiolites; AP, Arabian Plate; SSZ, Sanandaj–Sirjan Zone; UDMA, Urumieh-Dokhtar Magmatic Assemblage.

the hypotheses and the Zagros geology that are briefly described here below. The "Latest Cretaceous collision" hypothesis (Fig 4a) indicates that the back-arc Naien-Baft ophiolites and the Rollback related fore-arc Neyriz ophiolites, both are supra-subduction zone ophiolites. The hypothesis although can explain Zagros synchronous neighboring ophiolites but isn't able to justify the subduction related Urumieh-Dokhtar volcanic activity on the southwestern edge of the Central Iran Micro-Continent in Eocene time. The hypothesis proposed that the peak magmatic activity along the Urumieh-Dokhtar Magmatic Assemblage can be attributed to the post suturing slab break-off and rising of hot asthenosphere in the Middle Eocene. The main orogenic events, developed in the Early Pliocene are also remained without any reliable explanation. According to Shahabpour (2007), origination of the Urumieh-DokhtarMagmatic Assemblage in a continental island-arc setting and its sedimentary basins is related with changes in subduction angle of the Neo-Tethys oceanic plate underneath the Iranian terranes. According to Mouthereau et al. (2007) the first stage of deformation

in the Zagros foreland basin take placed in the early Miocene refers to the inversion tectonics of the Arabian margin. The structural and stratigraphic studies on the synorogenic deposits by Fakhari et al. (2008) indicate also that shortening and foreland basin sedimentation

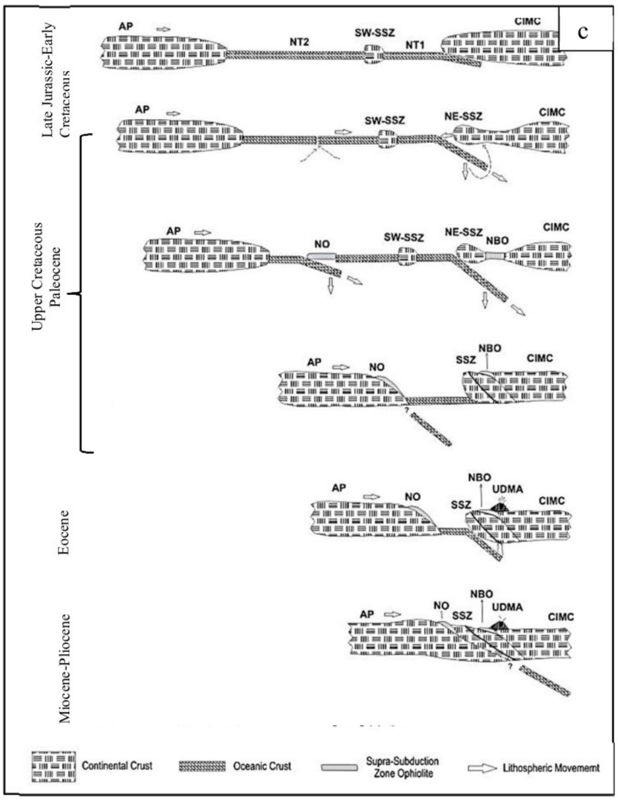

Fig 4. Continued

had commenced in the hinterland by the early Miocene. It can be deduced that the subduction of Neo-Tethys plate continued up to Miocene time. The "Neogene collision" hypothesis (Fig 4b) considers an intra-oceanic subduction zone in north of the Neo-Tethys mid-ocean ridge, in which the Neyriz ophiolites formed as rollback related fore-arc type and the Naien-Baft ophiolites takes as back-arc type, similar to former model. This hypothesis can explain Zagros synchronous neighboring ophiolitic rocks but some difficulties are also revealed as the followings:

- Spontaneous Sinking of young and hot oceanic lithosphere, near the mid-ocean ridge is not suitable.
- There is not any convincing reason for occurrence of the main orogenic event that developed at the ending of Cretaceous in Iranian terranes and closing the Naien-Baft back-arc basin.

Arfania and Shahriari (2009) reconstruct the tectonic evolution of the southeastern Zagros Orogn on the basis of "Latest Cretaceous-Neogene collision" hypothesis. According to Glennie (2000), Ghasemi and Talbot (2006) and Golonka (2007), the tectonic history of the southeastern part of Zagros Orogenic Belt involved the successive development of two belts of spreading oceanic crust that we refer to as Neo-Tethys 1 and Neo-Tethys 2 (Fig 4c). The "Latest Cretaceous-Neogene collision" hypothesis (Fig 4c) indicates; lithospheric compression was relieved when an induced subduction zone formed within Neo- Tethys 1, to the southwest of the central Iran Micro-Continent. Most of the Neo-Tethys 1 lithosphere was subducted by Late Cretaceous time, therefore increasing slab-pull leading to fast retreat (roll-back) of the subducting slab, trench suction and tension across the southwestern margin of the central Iran Micro-Continent. The northeastern Sanandaj-Sirjan (Esfahan-Sirjan Block) was pulled southwest and the Naien-Baft ophiolites formed in the back-arc setting. The sinking lithosphere additionally originated a down-dip component of movement that pulled the southwestern Sanandaj-Sirjan (Shahrekord-Dehsard Terrane) towards the Neo-Tethys 1 subduction zone and accelerated the northeastward movement of the terrane. This process led to creation of extensional setting in the Neo-Tethys 2 lithosphere that caused an unknown intra-oceanic weak zone rupturedand new oceanic lithosphere originated in the gap resulting from the extensional setting. The ruptured lithosphere then collapsed and a new intra-oceanic subduction zone initiated. The pull related Neyriz ophiolites formed in the fore-arc setting.The first obduction event stacked the Neyriz ophiolites in the Late Cretaceous (Santonian-Campanian), when the northeast margin of Arabian buoyant crust reached the trench. The Shahrekord-Dehsard Terrane come to the Neo-Tethys 1 trench at the ending of the Cretaceous and oceanic plate subduction was replaced by collision with the Central Iran Micro-Continent. The onset of collision coincided with the onset of surface shortening and the second obduction event stacked the Naien-Baft ophiolites.

6. Conclusions

The purpose of this paper was to reconstruct the tectonic evolution of the southeastern Zagros orogenic belts on the basis of new geological evidences about ophiolitic settings. The history of the southeastern Zagros Orogenic Belt is composed of development of two oceanic crusts, referred to as the Neo-Tethys 1 (between the Sharekord-Dehsard Terrane and the Central Iran Micro-Continent) and Neo-Tethys 2 (between the Arabian Plate and the Sharekord-Dehsard Terrane. The ophiolites from the supra-subduction zones in the southeastern Zagros Orogenic Belt can be divided into "pull related fore-arc Neyriz ophiolites" and "back-arc Naien-Baft ophiolites".

Acknowledgments

This work was supported by Islamic Azad University, Isfahan (Khorasgan) Branch, (research project: The northwest continuation of Abadeh Fault in Sanandaj-Sirjan Zone on the basis of fieldwork and remote sensing analysis).

References

Ahmad T, Posht-Kuhi M (1993) Geochemisty and petrogenesis of Urumiah–Dokhtar volcanics around Naien and Rafsanjan areas: a preliminary study, Treatise on the Geology of Iran. Tehran, Iranian Ministry of Mines and Metals*,* 90 p.

Alavi M (1994) Tectonic of Zagros orogenic belt of Iran: new data and interpretations, *Tectonophysics* 229: 211-238.

Alavi M (2004) Regional stratigraphy of the Zagros folded-thrust belt of Iran and its proforeland evolution, *American Journal of Science* 304: 1-20.

Amidi SM, Emami MH, Michel R (1984) Alkaline character of Eocene volcanism in the middle part of Central Iran and its geodynamic situation, *Geologische Rundschau* 73: 917-926.

Arfania R, Shahriari S (2009) Role of southeastern Sanandaj–Sirjan Zone in the tectonic evolution of Zagros Orogenic Belt, Iran, *Island Arc* 18: 555-576.

Azizi H, Chung SL, Tanaka T, Asahara Y (2011) Isotopic dating of the Khoy metamorphic complex (KMC), northwestern Iran: A significant revision of the formation age and magma source, *Precambrian Research* 185: 87-94.

Babaie HA, Ghazi AM, Babaie A, La Tour TE, Hassanipak AA (2001) Geochemistry of arc volcanic rocks of the Zagros Crush Zone, Neyriz, Iran, *Journal of Asian Earth Sciences* 19: 61-76.

Babaie HA, Ghazi A, Babaei A, Duncan R, Mahony J, Hassanipak A (2003) New Ar-Ar age, isotopic and geochemical data for basalts in the Neyriz ophiolite, Iran, *Geophysical Research Abstracts* 5: 12899.

Babaie HA, Ghazi AM, Babaei A, Arvin M (2006) Geochemical, 40Ar/39Ar age, and isotopic data for crustal rocks of the Neyriz ophiolite, Iran, *Canadian Journal of Earth Sciences* 43: 57-70.

Babaei A, Arvin M, Babaie HA (2001) An oblique convergence and rotation model for the emplacement of the Baft ophiolitic mélange in Iran, *Ofioliti* 26: 404-408.

Berberian M (1976) *Seismotectonic 1:2500000 Map of Iran, Tehran, Geological Survey of Iran*.

Berberian F, Muir ID, Pankhurst RJ, Berberian M (1982) Late Cretaceous and Early Miocene Andean-Type Plutonic Activity in Northern Makran and Central Iran, *Journal of Geological Society London* 139: 605-614.

Berberian M (1983) The Southern Caspian: A Compressional Depression Floored by a Trapped, Modified Oceanic Crust, *Canadian Journal of Earth Sciences* 20, 163-183.

Berberian M, King GCP (1981) Towards a paleogeography and tectonic evolution of Iran, *Canadian Journal of Earth Sciences* 18: 210-265.

Coleman RG (1981). Tectonic setting for ophiolite obduction in Oman, *Journal of Geophysics Research* 86: 2497-2508.

Colman-Sadd SP (1978) Fold development in Zagros simply folded belt, southwest Iran, *American Association of Petroleum Geologists Bulletin* 62: 984-1003.

Desmons J, Beccaluva L (1983) Mid-ocean ridge and island-arc affinities in ophiolites from Iran, palaeographic implications, *Chemical Geology* 39: 39-63.

Dilek Y, Furnes H (2009) Structure and geochemistry of Tethyan ophiolites and their petrogenesis in subduction rollback systems, *Lithos* 113: 1–20.

Dimitrijevic M (1973) *Geology of Kerman region. Institute for Geological and Mining Exploration and Institution of Nuclear and Other Mineral Raw Materials. Belgrad Yugoslavia*, 334 p.

Eftekharnejad J (1981) Tectonic division of Iran with respect to sedimentary basins, *Journal of Iranian Petroleum Society* 82: 19-28.

Falcon NL (1974) Southern Iran–Zagros Mountains, In: Anthony Mansell Spencer, (Ed.), *Mesozoic–Cenozoic orogenic belts. Geological Society, London, Special Publications* 4: 199-211.

Fakhari MD, Axen GJ, Horton BK, Hassanzadeh J, Amini A (2008) Revised age of proximal deposits in the Zagros foreland basin and implications for Cenozoic evolution of the High Zagros, *Tectonophysics* 451: 170-185.

Farhoudi G A (1978) Comparison of Zagros *Geology* to Island Arcs, *Journal of Geology* 86: 323-334.

Forster H, Fesefeldt K, Kursten M, Germany FR (1972) *Magmatic and orogenic evolution of the Central Iranian volcanic belt, 24th. IGC. Section* 2, 198-209.

Gansser A (1974) The ophiolitic mélange, a world-wide problem on Tethyan examples, *Ecologae Geologica Helvetica* 67: 479-507.

Ghasemi A, Talbot CJ (2006) A new tectonic scenario for the Sanandaj-Sirjan Zone (Iran), *Journal of Asian Earth Sciences* 26: 683-693.

Ghazi AM, Hassanipak AA (1999) Geochemistry, petrology and the origin of Shahr-Babak Ophiolite, Central Iran, *Ofioliti* 24: 96-107.

Glennie K W (2000) Cretaceous tectonic evolution of Arabia's eastern plate margin: A tale of two oceans, In: Abdulrahman S. Alsharhan, Scott, R.W. (Eds.), *Middle East models of Jurassic/Cretaceous carbonate systems. Society of Economic Paleontologists and Mineralogists, Special Publication* 69: 9-20.

Golonka J (2007) Geodynamic evolution of the South Caspian Basin, In: P. O. Yilmaz, Isaksen, G. H. (Eds.), *Oil and gas of the Greater Caspian area, American Association of Petroleum Geologists, Studies in Geology* 55: 17–41.

Hassanipak AA, Ghazi AM (2000). Petrochemistry, 40Ar–39Ar ages and tectonics of the Nain Ophiolite, Central Iran. In: *GSA Annual Meeting*, 237–238 pp.

Hassanipak AA, Ghazi M, Duncan R, Pessagno EA, Kariminia SM, Mobasher K (2003) Spatial and temporal distribution of Paleo- and Neo-Tethys ophiolites in Iran and their tectonomagmatic significance, *Geological Society of America Abs. with Prog* 34: 331.

Hessami K, Koyi HA, Talbot CJ, Tabasi H, Shabanian E (2001) Progressive unconformities within an evolving foreland fold- thrust belt, Zagros Mountains, *Journal of Geological Society London* 158: 969-981.

Jackson J, McKenzie D (1984) Active tectonics of the Alpine-Himalayan belt between western Turkey and Pakistan, *Geophysical Journal of the Royal Astronomical Society* 77: 185-264.

Jung D, Kūrsten M, Tarkian M (1976) Post-Mesozoic volcanism in Iran and its relation to the subduction of the Afro-Arabian under the Eurasian plate. In: Andreas P, Rosler A. (Eds.), *Afar Between Continental and Oceanic Rifting, Stuttgart, Schweizerbartsche Verlagbuchhandlung,* 216.

Lippard SJ, Shelton AW, Gass IG (1986) *The ophiolite of northern Oman, Geological Society London Memoir* 76:141-176.

Mouthereau F, Tensi J, Bellahsen N, Lacombe O, De Boisgrollier T, Kargar S (2007) Tertiary sequence of deformation in a thin-skinned/thick-skinned collision belt: The Zagros Folded Belt (Fars, Iran), *Tectonics* 26: 1-27.

Nouri F, Azizi H, Golonka J, Asahara Y, Orihashi Y, Yamamoto K, Tsuboi M, Anma R (2016) Age and petrogenesis of Na-rich felsic rocks in western Iran: evidence for closure of the southern branch of the Neo-Tethys in the Late Cretaceous, *Tectonophysics* 671: 151-172.

Ricou LE (1971) Le croissant ophiolitique péri-arabe. Une ceinture de nappes mises en place au Crétacé supérieur, *Rev. Geogr. Phys. Géol. Dyn*. 13: 327-350.

Ruban DA, Al-Husseini MI, Iwasaki Y (2007) Review of Middle East paleozoic plate tectonics, *GeoArabia* 12: 35-56.

Şengör AMC (1990) A new model for the late Palaeozoic-Mesozoic tectonic evolution of Iran and implications for Oman, In: Robertson AHF., Searle MP, Ries AC. (Eds.), the geology and tectonics of the Oman region, *Geological Society, London, Special Publications* 49: 797-831.

Shafaii-Moghadam H, Stern RJ (2015) Ophiolites of Iran: Keys to understanding the tectonic evolution of SW Asia: (II) Mesozoic ophiolites, *Journal of Asian Earth Sciences* 100*, 31-59*

Shafaii-Moghadam H, Whitechurch H, Rahgoshay M, Monsef I (2009) Significance of Nain– Baft ophiolitic belt (Iran): short-lived, transitional Cretaceous back-arc oceanic basins over the Tethyan subduction zone, *C. R. Geoscience* 341: 1016-1028.

Shahabpour J (2005) Tectonic evolution of the orogenic belt in the region located between Kerman and Neyriz, *Journal of Asian Earth Sciences* 24: 405-417.

Shahabpour J (2007) Island-arc affinity of the Central Iranian Volcanic Belt, *Journal of Asian Earth Sciences* 30: 652-665.

Sheikholeslami MR, Pique A, Mobayen P, Sabzehie M, Bellon H, Emami MH (2008) Tectono-metamorphic evolution of the Neyriz metamorphic complex, Quri-Kor-e-Sefid area, (Sanandaj- Sirjan Zone, SW Iran), *Journal of Asian Earth Sciences* 31: 504-521.

Stern RJ (2004) Subduction initiation: Spontaneous and induced, *Earth and Planetary Science Letters* 226: 275-292.

Stöcklin J (1968) Structural history and tectonics of Iran: A review, *American Association of Petroleum Geologists Bulletin* 52: 1229-1258.

Stöcklin J (1974) Possible ancient continental margin in Iran, In: Creighton Burk, Drake, C.L. (Eds.), The Geology of Continental Margins. Berlin, Springer, 873-887.

Stöcklin J (1977) Structural correlation of the Alpine ranges between Iran and central Asia. *Memoire Hors-Serie de la Societe Geologique de France* 8: 333-353.

Stoneley R (1990) The Arabian continental margin in Iran during the Late Cretaceous, In: Alastair Robertson, Searle, M., Ries, A. (Eds.), The Geology and Tectonics of the Oman Region. *Geological Society, London, Special Publications* 49: 787-795.

Taraz H (1974) Geology of the Surmagh-Deh Bid area, Abadeh region, central Iran. Tehran*, Geological Survey of Iran Report* 37: 104.

Topuz G, Göçmengil G, Rolland Y, Çelik ÖF, Zack T, Schmitt AK (2013) Jurassic accretionary complex and ophiolite from northeast Turkey: No evidence for the Cimmerian continental ribbon, *Geology* 41: 255-258.