

Tectonic evolution of the Khoy ophiolitic complex, NW Iran

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Received 19 February 2016; accepted 2 October 2017

Abstract

The Khoy Ophiolitic Complex (KOC) as a part of Tethyan, Izmir-Ankara- Erzincan and Bitlis-Zagros sutures of South East (SE) Turkey is broadly exposed around Khoy region (NW Iran). This complex comprises dismembered fragments of mantle lithosphere, obducted oceanic lithosphere and parts of volcanic arc remnants. The Khoy Ophiolitic Complex can be structurally divided into two major eastern and western blocks which is by NW-SE trending Khoy Faults with right-lateral strike slip kinematics. Also, with regard to heterogeneous crustal properties, KOC can be divided into accreted (stacks of imbricated thrusts) and obducted sections in the tectonic framework. The main tectonic events after opening of South Neotethys Ocean in Mid-Late Triassic include subduction, accretion, obduction and collision in KOC. Therefore, KOC can be regarded as one of the South Neotethyan oceanic relicts (similar to SE Anatolian ophiolites), and it has two distinct types of ophiolite, such that, each type has individual tectonic history related to accretion and obduction processes.

Keywords: *Khoy Ophiolitic Complex, Structure, Accreted, Obducted, Tectonic History.*

1. Introduction

Ophiolitic complexes, as on-land slices of fossil oceanic lithosphere, have the key role on recognition of plate tectonic history from sea floor spreading centers, subduction, collision, ophiolites emplacement to generation of paleo-suture zones and orogenies (Wakabayashi et al. 2003). Detail structural analysis is a key point in understanding the geodynamic evolution of orogenic systems. These structural investigations are crucial when ophiolite complexes have been trapped in the suture zones between two collided continents. Ophiolites of the Bitlis-Zagros suture zone, as a part of the tethyan ophiolite complex, are exposed along the curvilinear suture zones along the Zagros orogen in the Arabia-Eurasia continental collision zone (Fig 1). Khoy Ophiolitic complex (KOC) is considered as a part of Bitlis-Zagros suture zone ophiolites (Moores et al. 1984; Dilek and Delaloye 1992; Hassanipak and Ghazi 2000). This complex is also considered as the eastern termination of the East Anatolian Accretionary Complex (EAAC in Sengör and Yilmaz. 1981) at the Turkish-Iranian border in the northwestern corner of the Central Iran Block, as well as the eastern continuation of the Izmir-Ankara-Erzincan suture, where it connects to the Baft-Nain suture in Central Iran (Moazzen et al. 2012). The complex includes huge tectonic sheets of metamorphosed basement, ophiolitic rocks, volcanic and turbiditic rocks showing dismembered units of a classic ophiolite sequence (as determined by Penrose definition). Two separate complexes of ophiolitic rocks with different ages have been distinguished in KOC based on the geological, geochronological and

geochemical investigations. The western parts of the complexes have Late Cretaceous age and the eastern parts have Early Jurassic to Early Cretaceous age (Khalatbari-Jafari et al. 2003). The geochemistry and petrogenesis of the metamorphic rocks demonstrate that these complexes have been formed in an oceanic back-arc basin and then obducted over the island arc tholeiitic and calc-alkaline rocks of the adjacent arc system during the Late Cretaceous age (Azizi et al. 2006). Detail geochemical and microstructural analysis of ultramafic tectonites reflect a residual mantle sequence with high-temperature plastic deformation in upper mantle behavior of the complexes, which is consistent with a supra-subduction-zone environment and slow-spreading back-arc basin (Monsef et al. 2010). All previous works focused on the geochemistry, petrogenesis and geodynamic setting of the different rock types cropped out in KOC. However, their structural setting and evolution is almost neglected. This study describes the structural properties of the KOC generally based on field data. The new structural data set is then combined with previously published information about Neotethyan ophiolites to reconstruct the geodynamic evolution of KOC.

2. Geological Domains and Structures

The KOC is exposed in northwest of the Khoy city, which is located in the northwestern parts of Iran toward the Turkish-Iranian border (Fig 1). The area includes dismembered parts of ophiolitic and adjacent non-ophiolitic rocks with heterogeneous crustal properties. KOC and the adjacent areas can be structurally divided into two major eastern and western blocks, which is by NW-SE trending right-lateral strike slip main boundary fault zones (NW Khoy Faults in Fig 2 and 3).

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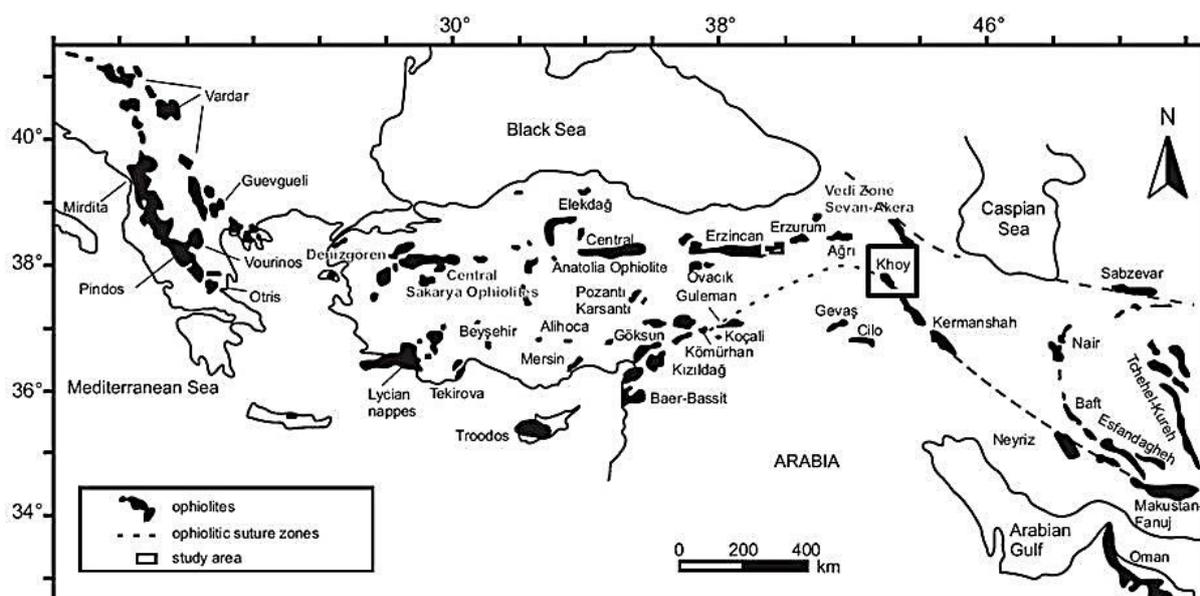


Fig 1. Study area on distribution map of the Neotethyan Ophiolites in the eastern Mediterranean region (after Sarifakioğlu et al. 2009)

The blocks have individual litho-tectonic properties. The eastern block, that comprises metamorphic series and ultra-mafic tectonites (with serpentinized harzburgite and lherzolite), thrust over each other, occasionally. In this block, ductile and ductile-brittle shear zones of NE dipping imbricated fans, imbricated thrusts, overthrusts and tectonic windows, are propagated. In other words, the eastern block is an imbricated unit of KOC. Refolding and folding of schistosity (metamorphic foliation) in meso and microscopic scale, between the mentioned thrust systems, are abundant. The western block includes juxtaposed units of the western metamorphic series, Cretaceous and post- Cretaceous volcanic, volcanogenic and turbiditic assemblages. The NE and SW dipping imbricated- fans and imbricated thrusts are the major structural features in this block.

In the tectonic framework, the ophiolitic series and the adjacent area can be divided into accreted and obducted parts (Fig 2).

I. Accreted part: This part includes Upper-Cretaceous thrust and juxtaposed units. The main units in this part are as follows:

a) Eastern metamorphic units cut by foliated granites are exposed at the northwest of the Khoy city, and according to Azizi et al. (2006) they can be divided into three rock assemblages of metabasites, metasediments and mylonitic granitoids.

From NE to SW (see structural cross sections in Fig 4), the Central Iran Block formations thrust towards the southwest and over the metamorphic complex while the complex itself thrusts over the Upper Cretaceous turbidities and volcano-sedimentary series. The complex

also contains tectonic window of metamorphosed ultramafic rocks and meta-ophiolitic series (Fig 3).

The eastern metamorphic complex is strongly deformed by ductile shear zones of thrust faults and shows visible sheared structures in meso- and microscopic scale. Foliated granites cut the complex, especially in the south of Qermezdash village (Fig 5).

The most recent U–Pb dating on zircon minerals from the metagranite and metabasite rocks suggests that the Khoy metagranites were generated in late Proterozoic (550–590 Ma), which is similar to the Iranian basement metagranites (Azizi et al. 2011). Khalatbari Jafari et al. (2004) introduced the eastern metamorphic complex as a subduction complex, because of the heterogeneity of the complex and existence of meta-ophiolites developed during most of the Mesozoic, at least from Lower Jurassic (Upper Triassic) to Upper Cretaceous.

More likely, the old granites have the basement affinities in the area and are exhumed during tectonic activities of ophiolites emplacement. This is discussed in more details below.

b) Imbricated units of huge tectonic sheets that include metamorphosed ultramafic/mafic rocks cut by micro-gabbros, show systematic tectonic contacts with the eastern metamorphic units. These highly tectonized rocks constitute a dismembered meta-ophiolitic assemblage, including meta-tectonites (serpentinized lherzolites and harzburgites) with mantle deformations, meta-cumulates (dunites, banded meta-gabbros and hornblendites), and various types of fine-grained amphibolites and meta-ankaramites (Khalatbari Jafari et al. 2004).

The imbricated units are deformed by right-lateral ductile shear zones of imbricated thrust systems in plastic conditions, whereas shear bands and sheared

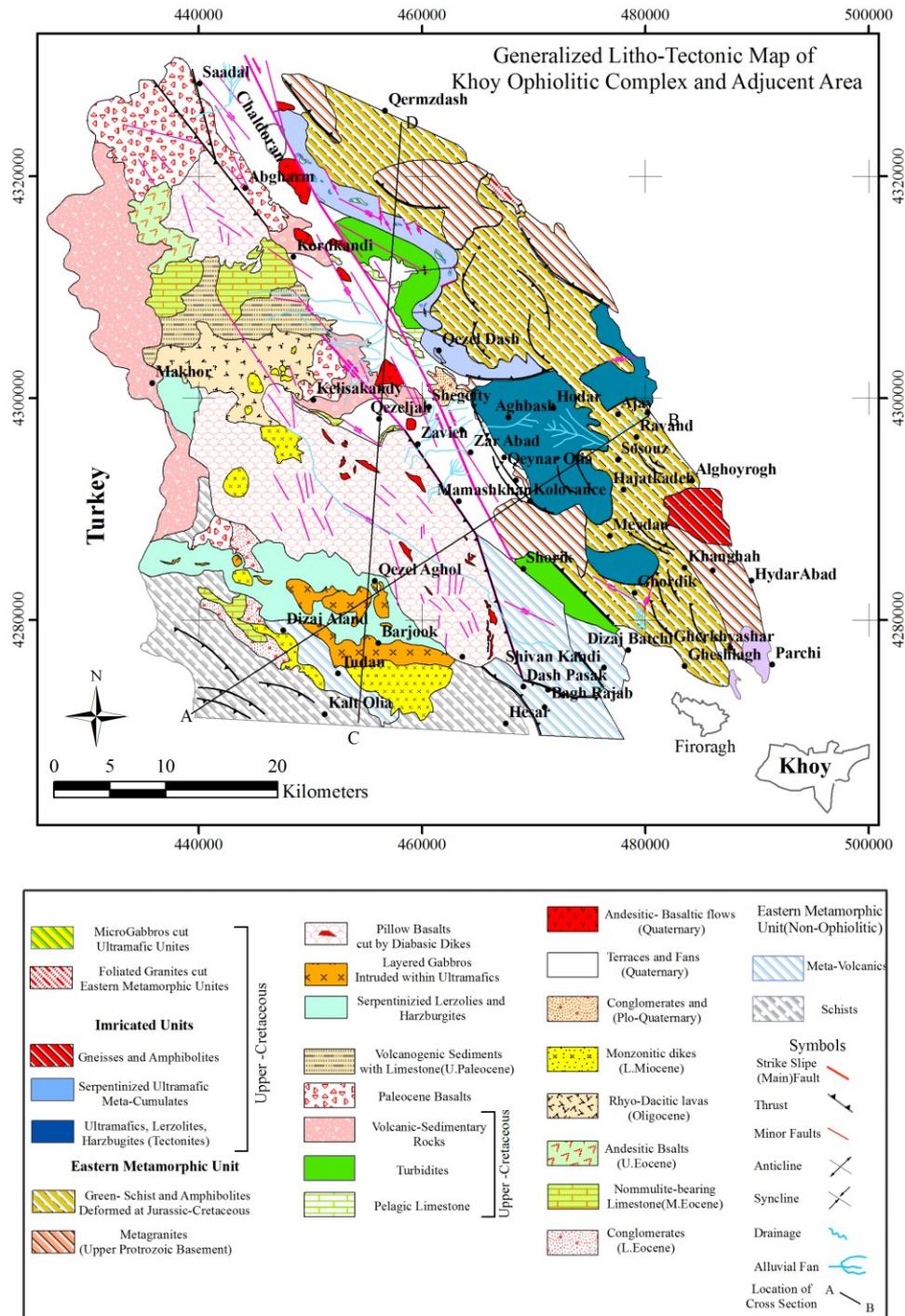


Fig 2. Geological Map of the KOC and the adjacent areas modified after Khalatbari- Jafari et al. (2004), AB and CD lines are the directions of drawn cross sections.

porphyroclasts in mylonitic texture occur at all scales. For example in the north of Hosseyan Abad Village, meta-gabbro dikes in the ultra-mafic rocks show bodinated scenery and imbricated anastomosed shear bands (Fig 6).

II. Obducted domain includes unconsumed and obducted units of early Upper-Cretaceous-lower Paleocene volcanic and plutonic series as follows:

a) Peridotites: This unit is highly serpentinized, it is crosscut by isolated diabase dikes and is in tectonic contact with the surrounded pillow lava by south and

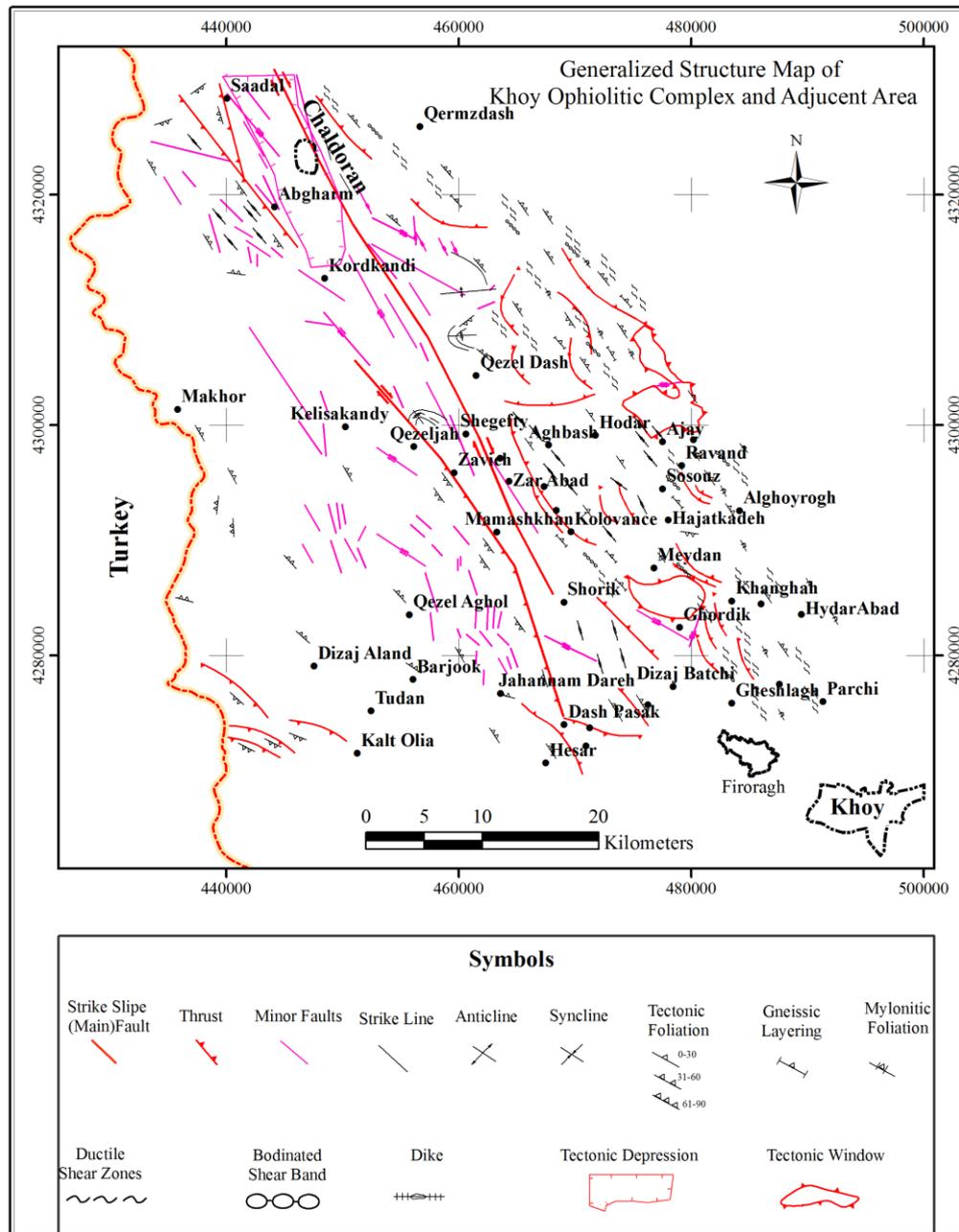


Fig 3. Structure map of the KOC and the adjacent area .

north dipping tectonic thrusts. Therefore, the peridotites show a pop-up structure.

b) Layered gabbros: This unit shows intrusive contact with peridotites and is interbedded within ultra-mafic rocks. Sills, veins and dikes of gabbro pegmatites and pyroxenites crosscut these layered cumulates, as well as numerous isolated diabase dikes (Khalatbari-Jafari et al. 2004).

c) Pillow basalts are broadly exposed at the western part of the study area which are cut by conjugate diabasic dikes.

These unmetamorphosed aphyric pillow basalts are tectonically overridden onto adjacent western and eastern metamorphic units by north and south dipping thrusts systems (Fig 7 and cross sections in Fig 4). Isotopic dating on feldspars of plagioclase-rich veins revealed ages of 72.6 ± 5.0 and 100.7 ± 6.0 Ma for the pillow basalts, which is compatible with the paleontological dating obtained on the ophiolites (Turonian to Campanian, 92–72 Ma). The diabasic dikes cut the huge volcanic pile of pillow basalt and display

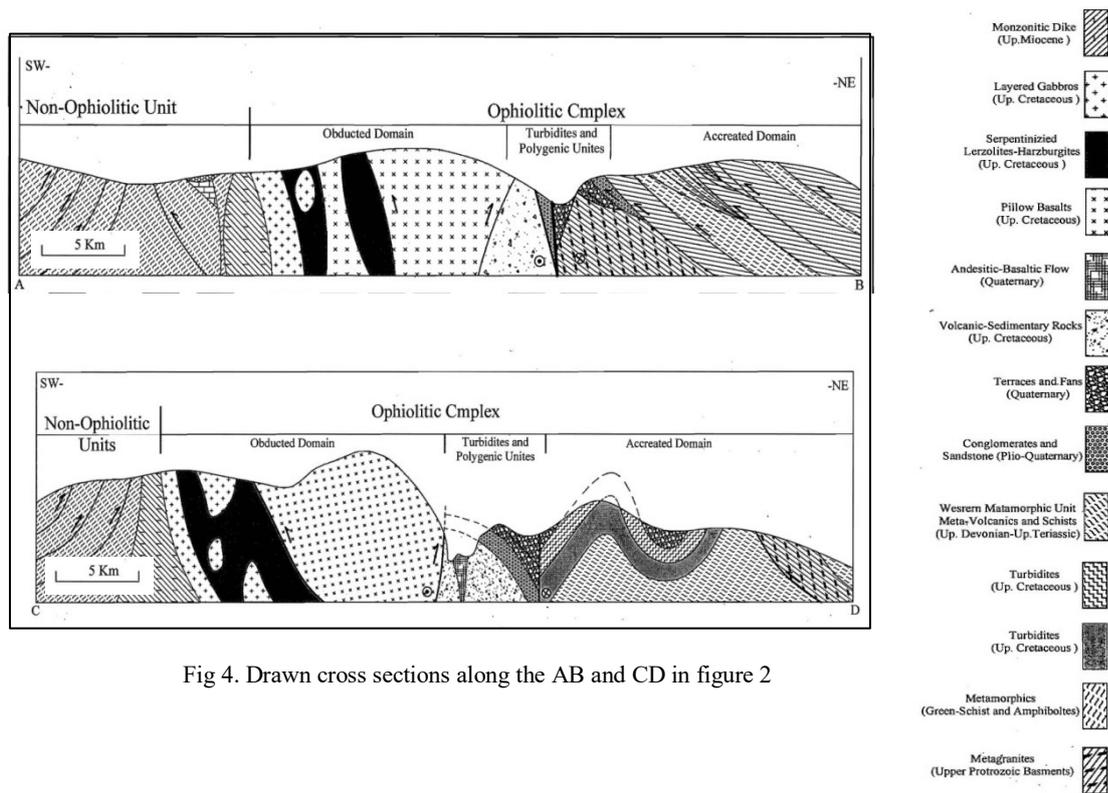


Fig 4. Drawn cross sections along the AB and CD in figure 2

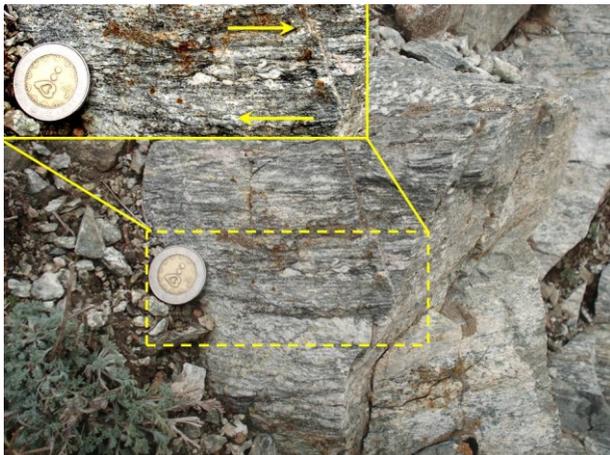


Fig 5. δ -type shear bands show right lateral ductile shear band in left hand parts of Khoys-Asgharabad road

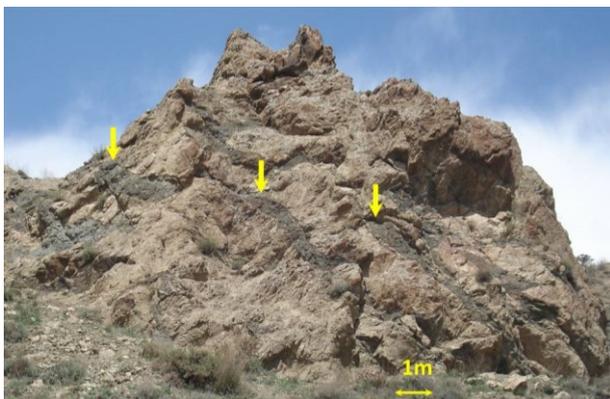


Fig 6. Bodinated and imbricated anastomosed shear bands in the shear zone with orientation of 45/070 at the north of Hosseyn Abad Village

Upper Cretaceous-Lower Paleocene boundary at 64.9 ± 3.8 Ma (Khalatbari-Jafari et al. 2004).

The non-ophiolitic units mainly include volcanic series, turbidites and volcanogenic fragments of various origins; which overlie the Cretaceous ophiolites, unconformably. The post-Cretaceous complex is accommodated by continuous brittle deformation as older strata in a thrust system (Fig 8-10). The main parts of the non-ophiolitic series are described as follows:

I. Volcanogenic series that includes:

- 1) Paleocene basaltic pillow lava is mostly brecciated and bounded by thrust and strike slip faults in central and northwestern parts of the study area.
- 2) Upper Eocene andesitic basalts have mostly pillow structures and the lavas tectonically overlain the post-Cretaceous turbidites and massive limestones.
- 3) Oligocene rhyodacitic lavas are exposed to the west of the study area. They consist of porphyric andesitic basalts, with subordinate pyroclastic breccias and rhyodacitic lavas. They are crosscut by monzodioritic-monzonitic dikes (Khalatbari-Jafari et al. 2004).
- 4) Miocene monzodioritic dikes intrude the ophiolitic series and post-Cretaceous sedimentary and volcanic rocks. Isotopic dating according to Khalatbari-Jafari et al. (2004) indicated upper Miocene (14-10.5Ma) age.
- 5) Quaternary andesitic-basaltic flows are restricted to the main boundary faults (Fig 2). The age of these lavas is Quaternary, ranging from 1.87 to 0.4 Ma (Allen et al. 2001). Based on field investigations, the young lavas are crushed along the strike slip faults.

II. Sedimentary sections

- 1) Upper Cretaceous pelagic limestone.
- 2) Paleocene-Late Eocene conglomerate.
- 3) Middle Eocene nomulite-bearing limestone.
- 4) Plio-Quaternary conglomerate and young terraces.



Fig 7. Elliptical pillow basalts in south of Kelisakandy village, the small yellow quadrangle is about 2×3 m

3. Tectonic Aspects

In the accreted domain, series of NE dipping imbricated units of mafic and ultra-mafic rocks (oceanic crust), upper Proterozoic metagranites (similar to the Iranian Continental Basement) and high –low temperature metamorphic rocks, can be seen (see drawn cross sections in figure 4). The metamorphic rocks that include green schists to amphibolites, were accommodated in emplacement of the ophiolitic complex during Jurassic upper Cretaceous (Khalatbari-Jafari et al. 2004) or have been formed as continental margin regional metamorphism.

Fingerprints of mantle deformations (Khalatbari-Jafari et al. 2004; Monsef et al. 2010) in the accreted domain indicate that the thrusts are superficial clues of detachment zones (Fig 3) or Ophiolitic napps in a trailing arrangement. The detachments resulted from the back thrusting of ascending oceanic slab in initial subduction of the eastern oceanic domain under the northwestern margin of the central Iran continental block. During the period, amalgamated mixture of heterogeneous crusts and also the accretion wedge ophiolites are generated in the accretionary prism.

Cretaceous pillow basalts of the study area have distinct affinities of mid oceanic ridge basalts on the basis of trace element patterns (Hassanipak and Ghazi, 2000). Therefore, the generation of the basalts occurred in the mid-ocean ridge spreading center that is related to the opening of Neotetys ocean. The ocean is believed to exist between Triassic–Late Cretaceous age (Şengör and Yılmaz 1981; Robertson and Dixon 1984; Yılmaz 1993; Robertson et al. 2007). The KOC is the eastern limit of Eastern Anatolian Accretion Complex (EAAC) which is composed of ophiolitic mélange and flysch, produced by

progressive consumption of Neotetys oceanic lithosphere (Şengör and Yılmaz 1981; Yılmaz 1990).

The study area comprises other basaltic rocks that have geochemical characteristics of ocean island basalt (OIB) located between MORB and accreted domain and pelagic limestone knockers (Moazzen and Oberhänsli 2008). The basalts range in age from Early Cretaceous (late Albian) to Early Tertiary (Early Middle Eocene in Pessagno et al. 2005). Therefore, the basalts display another disappeared intra-oceanic subduction zone in KOC. The intra-oceanic subduction zone was active until the formation of back arc basin that is believed to be the origin of peridotites from an Ophiolitic mantle sequence (Monsef et al. 2010).

The result from radiometric dating on the gabbros and amphibolites obtained by Ghazi et al. (1996) clearly suggests early Cretaceous (late Albian) age. Therefore, subduction-related metamorphism occurred at that time. Then, because of convergence between Bitlis microcontinent and the northwestern parts of the Iranian continent, Ophiolitic processes transformed into obduction of ascending oceanic crust and overriding of the unconsumed oceanic crust onto the adjacent eastern and western metamorphosed blocks. The events completed the subduction related accretion and the creation of accretion wedge of the metamorphed Ophiolitic series of upper Cretaceous. Also, the occurrence of upper Cretaceous-lower Paleocene volcanogenic and turbiditic sediments confirm the first suturing.

4. Discussion (Tectonic Evolution Model)

In order to propose a realistic tectonic evolution model, in accordance with the available data, the previous models are discussed here.

Kamineni and Mortimer (1975) assessed the metamorphic rocks and tectonic setting of the KOC. They suggested that the metamorphic rocks resulted from the increase in pressure and temperature occurring along or near the subduction zone during the Mesozoic-Neogene ocean closure. They emphasized that high pressure metamorphism is commonly associated with major thrust planes which were once subduction zones. Although their approach described the tectonic setting of thrusts in KOC, it could not analyze the emplacement mechanism and generation model for the accreted and obducted domains with inhomogeneous nature in the Khoy area.

Khalatbari-Jafari et al. (2004) and Juteau (2004) presented similar detailed geodynamic models that have good explanations about tectonic evolution of the KOC. However, their model cannot explain the tectonic environment of the following major units of the KOC:

- a) Metamorphic rocks adjacent to the mafic and ultra-mafic series, turbiditic and volcanogenic assemblages.
- b) Intra-oceanic island arc, distinguished by geochemical affinities.

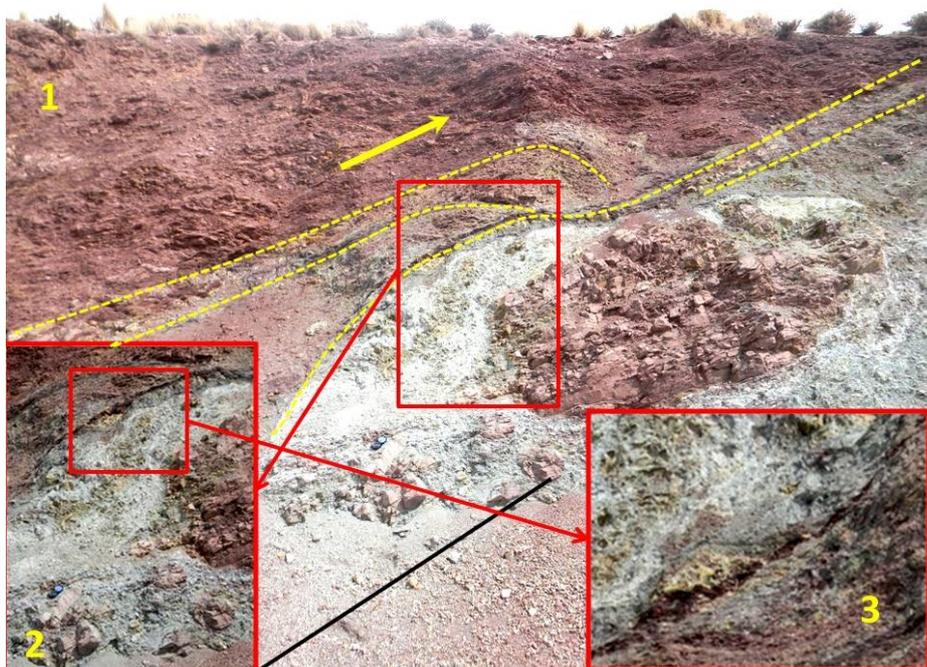


Fig 8. Some mezo-scale tectonic lenses in shear zone of thrust fault system-volcanogenic series- north of Qezeljah Village, part 2 is about 1.5×2 m and part 2 is about 0.5×0.5 m

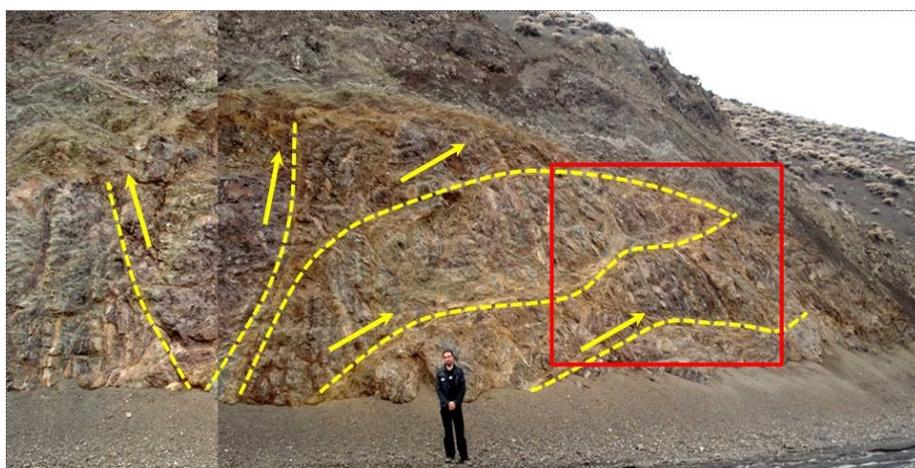


Fig 9. Thrusted units of the Upper Cretaceous volcano-sedimentary rocks in north of Kelisakandy village (the red rectangle is the next figure area)

c) Subduction related volcanism during the post-obduction and post-collision episodes.

Azizi et al. (2006) with respect to PTt path and geochemical affinities of the metamorphic rocks presented new geodynamic model for the KOC emphasizing on generation of island arc and back arc basins. According to their model, during the Late Cretaceous–Paleocene, a passive continental margin (Arabian plate) collided with the island arc. Deformation of the back arc basin was accompanied by formation of a tectonic mélangé between the island arc and Azerbaijan–Alborz block, probably in Late Eocene.

The immature oceanic crust of the back arc basin was obducted to the southwest onto the island arc.

Although the latest model considers the island arc and back arc basins, but with respect to cross sections of the obducted and accreted domains and adjacent units, the model has uncertainty in determining the tectonic environment of the arcs and the final juxtaposition status of the arcs and other adjacent parts in the Khoy region. Based on the above mentioned studies and the structural data presented here, the tectonic events (Fig.11) since opening of Neotethys up to the generation of the ophiolites in the Khoy area and the related tectonic events, is summarized below.

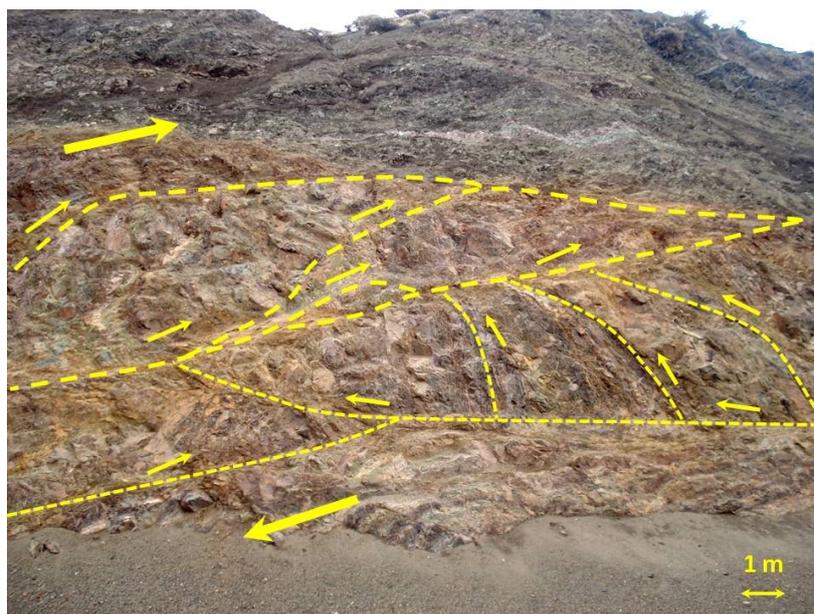


Fig 10. Semi-duplex thrust systems from eastern parts of figure 9

a) Middle to Late Triassic:

The time coincided with opening of Neotethys and peak extension of the oceanic domain that has been followed by final closure of Paleotethys (Şengör and Yılmaz 1981; Robertson and Dixon 1984; Robertson et al. 2007). There are not much significant tectonostratigraphic evidences for this event due to next tectonic overprints in the study area.

In the time interval, first subduction was initiated; because the Late Jurassic- Lower- Cretaceous subduction related metamorphism in the area (Khalatbari-Jafari et al. 2004) was the main time of starting the tectonic events followed by the more complex tectonic activities during Cretaceous to Lower Paleocene.

b) Middle Cretaceous- Lower Paleocene

During the Cretaceous stage (~140--~80 Ma), north-south directing convergence between African and Eurasian plates became accelerated and Neotethys oceanic crust. Tectonic evolution in the KOC is remarkable at this time. The first subduction initiated during early Cretaceous and related metamorphism was at the peak during the time. The subduction development was followed by deep back-thrusting of ascending oceanic crust and obduction of amalgamated mixture of mantle rocks (from benioff zone), mafic- ultramafic rocks (accretionary –wedge ophiolites), continental margin basement rocks and metamorphic rocks generation. Another evidence for the short lived subduction is the peraluminous S-type granitoids reported by Farid Azad (2009).

Some workers estimated that 90% of the force needed to drive the plates comes from the sinking of lithosphere in subduction zones, with another 10% coming from ridge

push (e.g. Bertelloni and Richards 2004). Therefore, it can be postulated that first ascending oceanic crust under the NW-Iranian passive continental margin by gravitational force, supplied enough forces to generate new oceanic ridges. The ridges produced the Upper Cretaceous MORB.

Pessagno et al. (2005) reported the geochemical affinities of some basaltic rocks with volcanic arc basalt (VAB) nature that were located between MORB and eastern accreted domain. The VAB can determine an intra-oceanic subduction in west of the initial subduction. There is no significant tectonostratigraphic evidence for the presence of VAB.

During the Upper Cretaceous to Lower Paleocene, persisting extension caused formation of back arc basin spreading centers, represented by ultramafic tectonites of the residual mantle sequence. Two types of tectonites are found:

a) Fingerprints of fertile abyssal peridotites after segregation of MORB magma at a slow-spreading back-arc basin, and

b) Depleted abyssal peridotites and basaltic magma extraction in a supra-subduction-zone environment (Monsef et al. 2010).

During the subduction, oceanic crust was consumed and amalgamated mixture of accreted terrains and arcs collided. This time points the initial suturing in the KOC. Obduction of the unconsumed young and low density MORB and probably parts of VAB in both west and eastern sides occurred, similar to pop-up zones during Lower Paleocene.

c) Upper Paleocene to Miocene (~60 --~5Ma)

After Upper Cretaceous to Lower Paleocene tectonic events, there were other tectonic pulses related to the creation of post- Cretaceous deep sedimentary basins

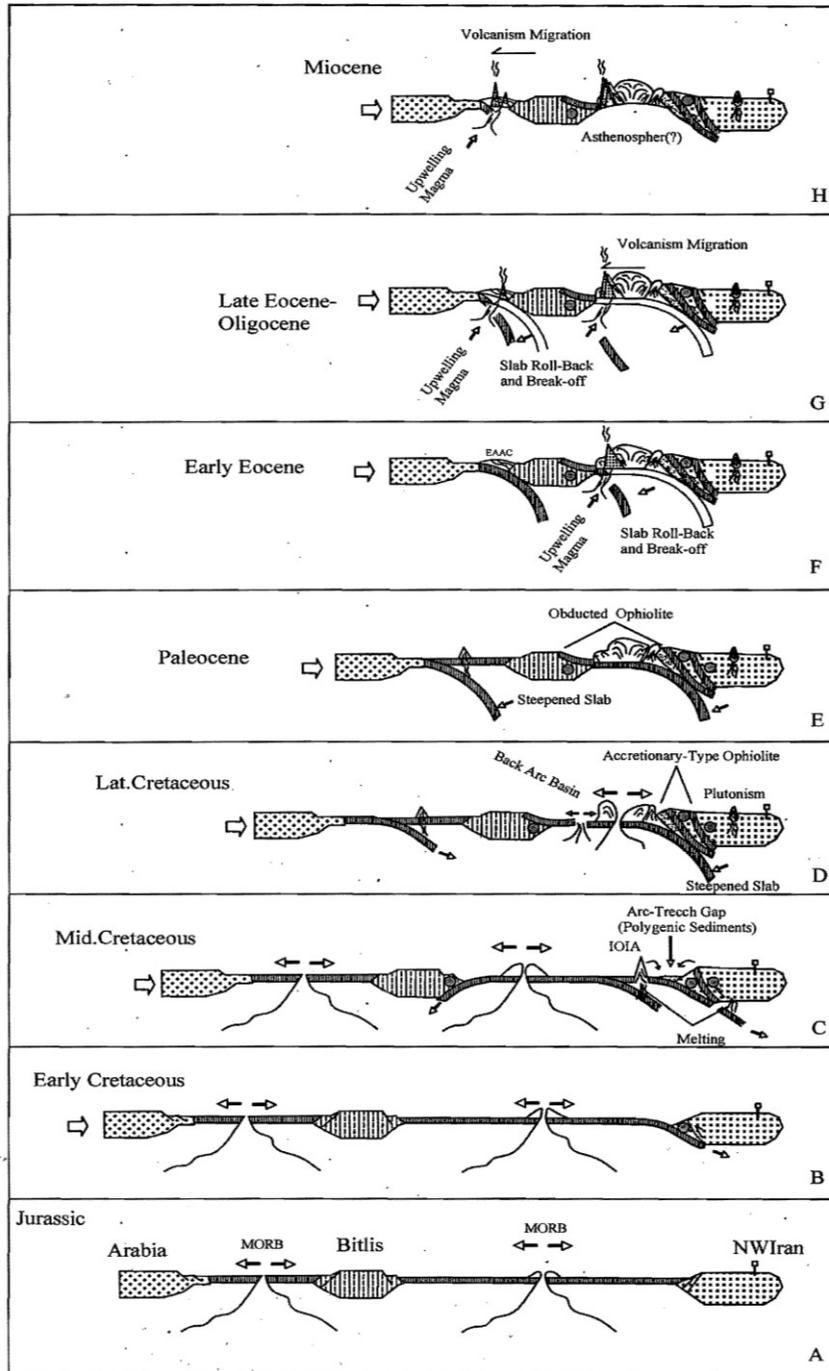


Fig 11. Schematic model shows the geodynamic evolution of KOC

followed by dacitic and andesitic volcanism and calc-alkaline monzonitic to monzodioritic intrusions of Miocene age (Khalatbari-Jafari et al. 2004). The intrusions have age and geochemical properties similar to monzonite plutons reported from northeast Turkey, close to the Turkey–Iran border according to Çolakoğlu and Arehart (2010). They conclude that the high-K, calc-alkaline plutons are clearly subduction-related. The magmatic belt is parallel to the suture zone between the EAAC and the continental crust of the

Eurasian continent and was associated with the final closure of the Neotethys Ocean. Perhaps the magmatism had activities after the initial collision and suturing in the KOC. In the study area, upper Paleocene to Miocene volcanic rocks cut the western parts of the KOC. The volcanics became calc-alkaline and younger from northwest towards the southeast (Fig 3). The subduction-related volcanism can show the migration of volcanic activities that resulted during the changing of the position of

hidden sunk slab. The changes in nature of volcanics show slab roll-back mechanism proposed by Keskin (2003, 2005), as an alternative model for collision-related volcanism in Eastern Anatolia.

5. Implications for evolution and closure of the Neotethys

The two well-known sutures in the eastern parts in Middle East are Izmir-Ankara- Erzinçan that suggests southward polarity of subduction for the Palaeo-Tethys (Okay et al. 2014) and Assyrian-Zagros or Bitlis-Zagros sutures that separates the Anatolide-Taurid block from the Pontide continental fragments and the Arabian Platform (Obrehaensli et al. 2012). The Anatolide-Taurid block includes different metamorphic and structural features such as thrust sheet of ophiolites, metamorphic rocks, flysch and accretionary complex.

The KOC is located between the sutures similar to the SE Anatolian late cretaceous ophiolites such as Guleman and Killan ophiolites. Therefore, KOC can be regarded as eastern limit of the SE Anatolian ophiolite series as relicts of Southern Neotethys.

It can be assumed that Neotethys opening was contemporaneous with final closing of Paleotethys during upper Triassic-lower Jurassic, and it was at its widest condition during middle Jurassic and finally closed in Middle Miocene (Robertson et al. 2007 and references therein).

6. Conclusions

Based on geological, geochemical and structural field data, KOC includes two distinct parts in the framework of tectonic environments: a) accreted and b) obducted ophiolite realms. The domains were affected by the various emplacement mechanisms during the time of accretion and obduction processes.

During Lower Jurassic- Early Cretaceous time, short-lived subduction was initiated and first oceanic slab was subducted beneath the Iranian passive continental margin. Fundamental deep back-thrusts and overthrusts (not metamorphic soles) caused accretion of mafic, ultramafic and HP-LT metamorphic rocks. This resulted to the exhumation of accretion-type ophiolite. In addition, syn-tectonic ductile shear zones and regional metamorphism are remarkable in the accreted domain. Contemporaneously, generation of MORB in ocean floor spreading centers was accompanied by the second intra-oceanic subduction and back-arc basin evolution. Then, further convergence caused subduction cessation and obduction of unconsumed oceanic lithosphere. During late Cretaceous- early Paleocene age, further convergence induced obduction of the remnant lithosphere on the west and eastward adjacent blocks and therefore, obducted ophiolite was generated.

After emplacement of ophiolites in the KOC, deep sedimentary basins and dacitic and andesitic volcanism and calc-alkaline monzonitic to monzodioritic intrusions of Miocene were intruded. The volcanics cutting the

western parts of the KOC are probably showing subduction related affinities and depicts the syn- to post-collision roll-back mechanism of the subducted slab. More studies are needed to prove the latter. Therefore, main tectonic pulses (see figure 11) can be summarized consequently as:

(1) N-dipping Subduction of the oceanic crust below NW-Iranian passive continental margin and metamorphism related to short-lived subduction during Lower Jurassic – Lower Cretaceous; (2) After the ophiolite formation, deep back-thrusting of ascending oceanic crust and obduction of tectonic mixture of mantle rocks (from the benioff zone), mafic-ultramafic rocks (future accretionary –wedge ophiolites), continental margin basement rocks and engaged metamorphic rocks created a tectonic mélange during Mid-Cretaceous age. (3) Contemporaneously, when the first oceanic crust ascended under the passive continental margin by gravitational force, enough forces have been supplied to generate the Upper Cretaceous MORB. Also, based on geochemical evidence, ocean island arc basalt (OIB) was located between MORB and eastern accreted realm. The arc could have been generated by second (intra-oceanic) subduction zone. (4) During the Upper Cretaceous to Lower Paleocene age, a back arc basin spreading center was developed. The basin is distinguished by ultramafic tectonites of residual mantle sequence. Following the subduction, oceanic crust was consumed and amalgamated mixture of accreted terrains collided with the arc. This is the initial suturing time in KOC. (5) Since the collision, the unconsumed young and low dense MORB and probably parts of OIB (future supra-subduction ophiolite) obducted on both west and eastern sides similar to pop-up zones during Lower Paleocene. (6) Generation of Post-Cretaceous deep sedimentary basins was followed by post-collision dacitic and andesitic volcanism and calc-alkaline monzonitic to monzodioritic intrusions of Miocene. More likely, magmatism reached its climax after the initial collision and suturing in KOC in the time intervals by roll-back mechanism of subducted slab.

Acknowledgment

We are grateful to Dr Moazzen and Dr. Maadanipour for their critical reviews. Editors and reviewers of the Iranian Journal of Earth Science are thanked for reviewing the first version of the manuscript.

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