



## Tectonosedimentary evolution of the basins in Central Alborz, Iran

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### ABSTRACT

Evidence of at least ten different tectonic- controlled sedimentary basins can be recognized in the central part of the Alborz Mountains in the Middle part of the Alpine-Himalayan belt. They formed from Neoproterozoic to recent time as the results of the relative plate motion in southwest of Asia in Tethyan realm. The basins include: (1) Prototethys Late Neo-Proterozoic to Early Ordovician epi-continental/platform basin; (2) Paleotethys Middle Ordovician to Devonian rift basin; (3) Devonian to Middle Triassic continental shelf basin; (4) Upper Triassic to Lower Jurassic foreland basin; (5) Shemshak back arc rift basin; (6) South Caspian carbonate platform basin; (7) Paleocene clastic sedimentary basin; (8) Karaj back arc basin; (9) Oligo-Miocene foreland basin; (10) Pliocene-Pleistocene intramontane basin. Each basin has its own unique history connected to the different stages of the birth, development and destruction of the Prototethys, Paleotethys and Neothethys Oceans in the Middle East region in the southwest of Asia.

### 1- Introduction

Interaction between the African and Eurasian plates has generated a broad collision zone comprising the Alpine-Himalayan chain running from Southeast Asia to southwest Europe (Lopez and Cunha, 2007). In the case of the Alborz Mountains located at the NE of this zone, opening and closure of the Paleotethys and south Caspian basins have had the most important control on the formation of different sedimentary basins. Although several geological models have been proposed for the tectonic evolution of the Alborz in order to explain the mechanism and timing of geodynamic evolution from incipient continental rifting through its oceanic state to its closure by subduction and continental collision (Stocklin, 1974; Alavi; 1996; Allen et al, 2003; Zanchi et al., 2006; Guest et al., 2006; Nazari, 2006; Shahidi, 2008), tectonostratigraphic data and interpretation of their bearing on the tectonic environment of the rocks in this part of Iran are needed to constrain and refine these various tectonic models. This paper aims to reconstruct the possible geodynamic evolution of the Central Alborz primarily based on the record of different tectonostratigraphic units related to evolution of the Tethys Ocean in northern part of Iran. This classification will help to generalize a tectonosedimentary framework for more detailed works.

### 2- Geological setting

The Alborz Mountain in north of Iran is extended from Azerbaijan in the NW into Khorasan in NE. The Central Alborz runs from west to east along the southern coast of the Caspian Sea. This part of the Alborz comprises an 11 to 13 km thick rock units from Neoproterozoic to Quaternary ages (Zanchi et al., 2006). These rock are affected by succession of deformations related to the Cimmerian and Alpine events. About 3000 m of Precambrian and Cambrian shallow-marine sandstones and dolostones, with Lower Cambrian continental deposits, form the base of this succession. Lower-Middle Ordovician shales and siltstones are covered by Silurian lava flows around Ramsar city (Zanchi et al., 2009). Devonian to Middle Triassic succession in the Central Alborz consists of the shallow marine carbonates intercalated with basaltic lava flows, transformed to widespread carbonate platform sedimentation in the Triassic known as Elika Formation. This succession is unconformably covered by the siliciclastic deposits of the Shemshak Group of Upper Triassic-Lower Jurassic age. The shallow water Upper Jurassic-Cretaceous carbonate succession is unconformably covered by the Paleocene Fajan continental conglomerates. They are succeeded by a thick sequence of the Eocene volcanic and volcano-clastic rocks of the Karaj Formation.

The Miocene succession consists of coastal fine-grained terrigenous units with evaporites and limestones. Continental Plio-Quaternary uplifted and deformed conglomerates are widespread, especially along the frontal parts of the belt (Zanchi et al., 2006) (Fig. 1).

### 3- Tectonostratigraphic framework of the Central Alborz

As a pioneer, Alavi (1996) classified the different rock

units of the Alborz Mountains in the frame of the seven tectonostratigraphic units and a number of metamorphic assemblages. The tectonic and sedimentary features of these units was later studied by Allen et al., 2003; Guest et al., 2006; Zanchi et al., 2006; Fursich et al., 2009a; Wilmsen et al., 2009. Based on these studies, the following tectonostratigraphic framework can be considered for the Alborz Mountains in north of Iran (Fig. 2).

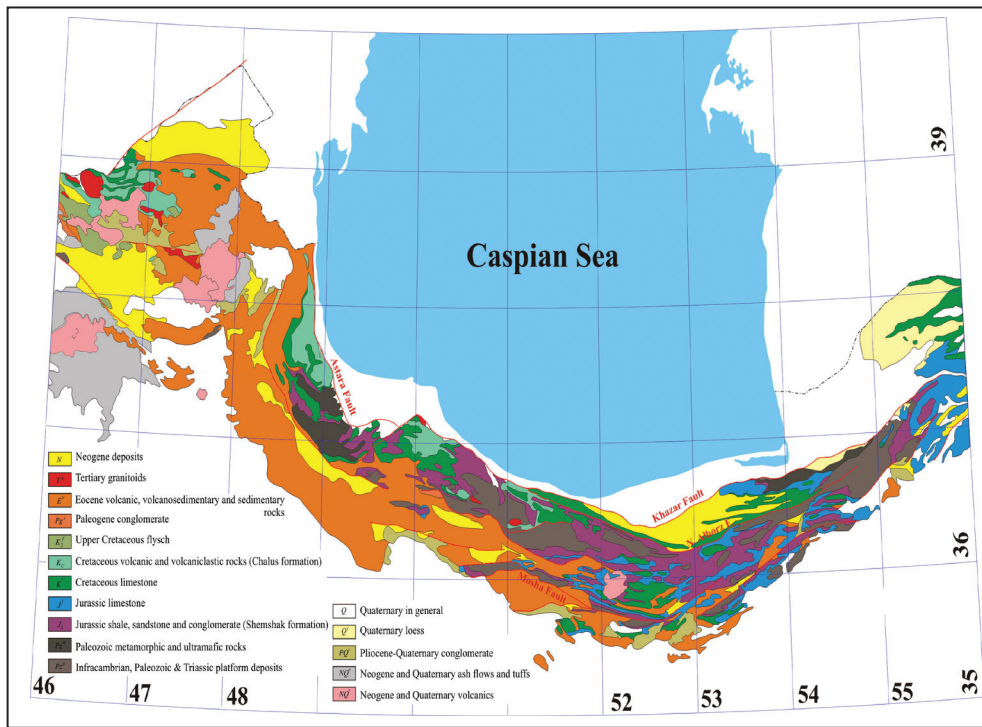


Fig. 1- General geology and tectonic map of north Iran and of the South Caspian basin. (Ghassemi, 2004).

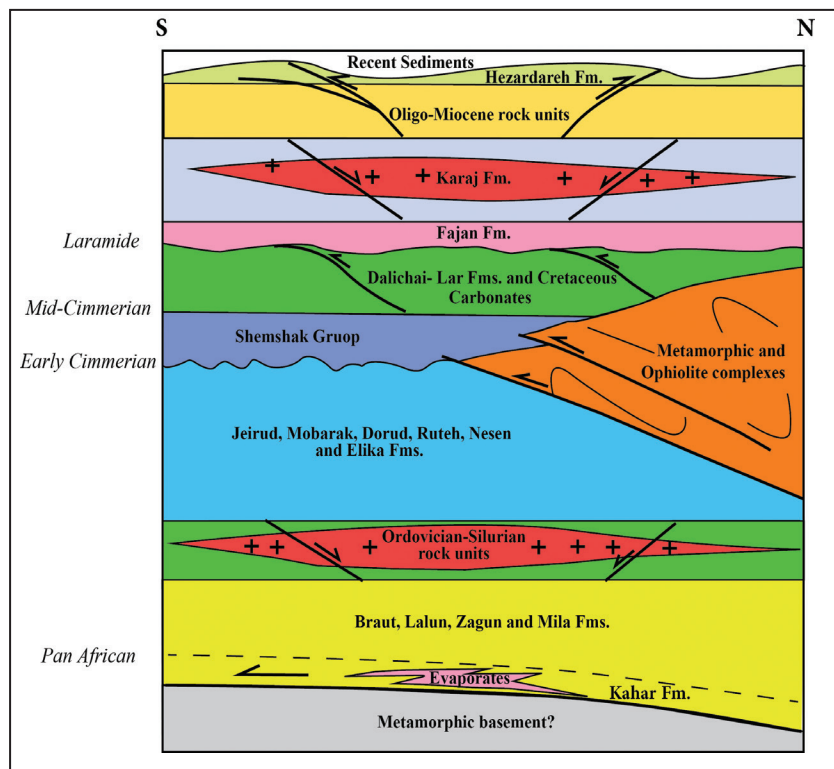


Fig. 2- Main tectonostratigraphic units of the Alborz region (not to scale). Modified after Allen et al. (2003) and Guest et al. (2006).

During Late Proterozoic to Ordovician time a shallow epicontinental basin was developed in the present-day Alborz region. Sedimentation in this basin was started by siliciclastic deposits of the Kahar Formation containing mudstone, sandstone and conglomerate. The lack of outcrops of metamorphic basement and appearance of the Kahar Formation at the base of several nappes in Central Alborz (Bashm area) has been interpreted as indicator of the major detachment horizon below the Kahar Formation (Allen et al., 2003). Gypsum and anhydrite lenses along the thrust sheet support the idea that the Kahar Formation may compare with other Gondwanian strata such as the Hormuz salt deposits which formed on the north Gondwana realm (Fig.2). Southeast of Damavand, the Kahar Formation was affected by successive folding and generation of the axial plane foliation. Since this deformation is not observed in overlying sequence, it can be considered as evidence of Pan African event. The Kahar Formation is overlain by a transgressive facies of the Soltanieh Formation containing shale, dolomite and dolomitic limestone. During Early Paleozoic time successive retrogression and transgression of the sea level dominated in the area, resulting the epi- continental to platform deposition of the Barut, Zagun and Lalun and Mila Formations (Lasemi, 2001).

Ordovician to Middle Devonian was the time of breakup of the Alborz region resulted in eruption of magmatic rocks and associated sedimentation. The main outcrops of these rocks are found in eastern Alborz (Alavi, 1996).

The Devonian–Middle Triassic rock units were deposited in a shallow-marine ramp carbonates and development of Jeirud, Mobarak, Dorud, Ruteh and Nesen Formations. This sedimentary condition transformed to carbonate platform which marked by deposition of Elika Formation. Intercalated siliciclastic units and unconformities occur within the Lower Carboniferous carbonates of Mobarak Formation at the base of the Permian Dorud Formation. This succession is marked by several uplifts, possibly due to the effects of distant tectonic events (Gaetani et al., 2009).

Following to deposition of Lower–Middle Triassic platform carbonates of Elika Formation, the Shemshak Group deposited after a drastic change in depositional condition due to Early Cimmerian tectonic event (Fursich et al., 2009b). This event caused thrusting and final exhumation of deformed and metamorphosed fragments of the Upper Paleozoic European continental crust including Gorgan schist as well as Gasht and Shanderman complexes on the northern edge of the Iranian plate in present-day Alborz region (Alavi, 1996; Zanchi et al., 2006; Zanchetta et al., 2009).

The Shemshak Group was deposited in the marine to non-marine settings, including lacustrine, fluvial deltaic deep marine and basinal environments (Fursich et al., 2005). In the Alborz Mountains, the group consists of a Triassic and a Jurassic unit, separated by an unconformity, which is in part angular in the northern part of the mountain range and less noticeable towards the south (Fursich et al., 2009a). Thick basaltic lava flows and gypsum commonly occur above the unconformity, especially in the southern Alborz (Zanchi et al., 2009).

The Bajocian unconformity related to Mid Cimmerian event terminates the sedimentary cycle of the Shemshak Group in Alborz and Central Iran. This event might be responsible for the change from the rifting to the spreading stage of the South Caspian Basin in present-day Alborz region (Fursich et al., 2009b). The result is Middle Jurassic to late Cretaceous epicontinental to continental platform sediments of the Dalichai and Lar Formations as well as Cretaceous carbonate. This condition resulted in high rates sedimentation, considerable subsidence and rapid thickness of the basin all suggested onset of a regional extension in northern Iran (Fursich et al., 2005, 2009a; Wilmsen et al., 2009).

The Jurassic-Cretaceous carbonate succession is unconformably covered by the Paleocene Fajan conglomerates. This clastic basin were formed after the Late Cretaceous compressional event and occurred to the south of Paleotethys margin in present-day Alborz region.

These rocks succeed by Eocene Karaj Formation containing volcanic and volcanoclastic rocks unconformably overlies the older deformed sequences. This Formation displays evidence of syn-extensional deposition which interpreted to record back arc extension and subsidence in northern Iran during Eocene time (Berberian, 1983; Allen et al., 2003; Guest et al., 2006; Verdel et al., 2011). In the southern part of the Central Alborz, the Karaj Formation is unconformably overlain by a sequence of Oligocene-Miocene volcanic rocks and marine carbonates which are unconformably overlain by Middle to late Miocene conglomerate (Guest et al., 2006). These basins possibly formed in a foreland basin developed at the front of the growing Alborz belt. The Pliocene-Quaternary sediments including Hezardareh and Kahrizak Formations are characterized by coarse- to fine-grained polymictic conglomerate deposited in a fluvial regime (Alavi, 1996). This succession resulted from late Alpine folding and faulting which caused the formation of intramontane siliciclastic basin. These sediments are deformed and uplifted by active faults including Firuzkuh, Mosh, North Tehran and Khazar faults (Zanchi et al., 2009).

#### 4- Tectonic setting of the basin in Central Alborz

The above-mentioned Late Proterozoic to recent tectonostratigraphic units from the Central Alborz were formed in the different tectonic -controlled basins represents a unit of geological structure. These basins were filled up with sediments unique to each basin during a given span of time. Different sedimentary basins which are formed in Central Alborz are classified below from the oldest to recent ones:

##### 4-1. Prototethys Late Neo-Proterozoic to Early Ordovician epi-continental/platform basin

Based on lithofacies features two types of synrift and postrift sediments were formed in prototethys basin (Lasemi, 2001).

- **Synrift passive marginal basin:** The siliciclastic sediments of Kahar Formation are supposed to be deposited in the marginal part of the extended Prototethys rift (Lasemi, 2001). Petrographic and geochemical investigation of the Kahar rocks indicate that this rift may

be originated from a back arc basin formed in the rear of a volcanic arc related to subduction of Prototethys Ocean beneath the north Gondwana plate in Late Edicaran time (Etemad-Saeed et al., 2015)(Fig.3 - a and b). Zanzan schists as well as Doran granite in western Alborz, and Mayamey granite in the eastern Alborz can be considered as the metamorphic and magmatic activities related to this convergence (Ghadimi et al., 2012; Sadeghian et al., 2017).

- **Post-rift passive marginal basin:** Following the formation of the early rift and spreading of the Prototheys Ocean in a back arc setting, rift-related subsidence and further growth of the basin led to the transgressive facies of the Soltanieh Formation deposited on the northern margin of the Gondwana continent. Subsequent and alternately retrogression and transgression of the sea level led to the epi- continental deposition of the Barut, Zagun and Lalun Formations in intermediate to continental environments and to carbonate platform Mila Formation (Lasemi, 2001).

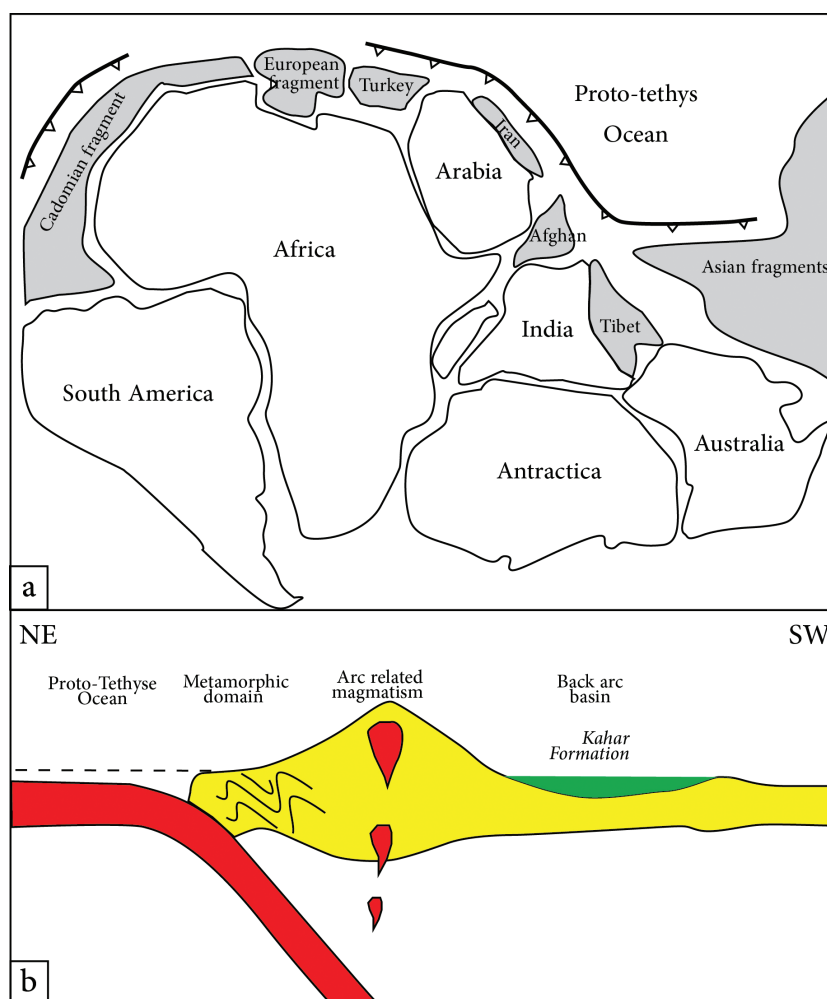


Fig. 3- a) Map of Gondwana at the end of Neoproterozoic time. Modified after Kusky et al. (2003); b) Schematic illustration represents the possible tectosedimentary settling for deposition of the Kahar Formation at the northern Gondwana margin. Modified after Etemad-Saeed et al. (2015).

#### 4- 2. Middle Ordovician to Devonian Paleotethys rift basin

At Early Ordovician time, due to increase of regional extension related to the opening of the Paleotethys Ocean, global decreasing of the sea level is caused disappearance of the carbonate platform and the emergence of significant unconformity between these sediments and Ordovician volcanic and sedimentary rocks. The main outcrops of these rocks are found in eastern Alborz. The large thickness of Lower Paleozoic sediments associated with mainly volcanic and fewer plutonic rocks indicate presence of a rift basin in northern limb of the Alborz Mountain (Clark et al., 1975; Derakhshi et al., 2014). The volcanic part contains fine-grained pyroclastic and volcanoclastic rocks as well as andesitic and splitic lava flows partly show pillow structures. The plutonic rocks contain gabbro and diorite (Alavi, 1996).

#### 4- 3. Devonian to Middle Triassic continental shelf basin

This basin characterized by a thick continental ramp to shelf succession formed in the Paleotethys divergent margin (Stampfli et al., 1991; Alavi 1996; Lasemi, 2001; Sardar Abadi et al., 2015). Paleontological investigation based on conodonts and brachiopods within the succession show the evolution of the basin from a shallow carbonate-dominated shelf in the Silurian which was transformed into a siliciclastic shelf during the Early Devonian times (Wendt et al., 2005). Marine conditions were later dominated in the Middle Devonian to Early Frasnian and persevered until the Late Carboniferous. A widespread uplift in the latest Carboniferous transformed the area into a continental regime before the onset of a new marine cycle during the late Early Permian.

The succession is locally intruded by gabbro and diabasic rocks probably related to the former Ordovician Early Devonian magmatic activities (Alavi, 1996)(Fig. 4). Geochemical studies of Permian volcanic rocks in central Alborz show an intra-plate tectonomagmatic setting, during the Permian and development of a passive continental margin along the southern border of Paleotethys (Delavari et al., 2016).

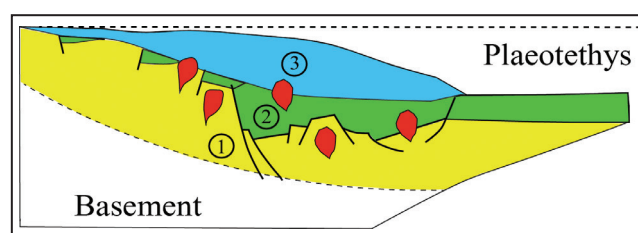


Fig. 4- Possible tectono-sedimentary basin for deposition of the Devonian to Middle Triassic continental shelf sediments. Numbers indicate: 1) Prototethys Late Neoproterozoic to Early Ordovician epi-continental/platform; 2) Paleotethys Middle Ordovician to Devonian rift basin; 3) Devonian to Middle Triassic continental shelf sediments.

#### 4- 4. Upper Triassic to Lower Jurassic foreland basin

The formation of a foreland basin during Upper Triassic-Middle Jurassic times in front of the uplifted area in the present day Alborz Mountain was firstly outlined by Alavi (1996). This basin was later filled with Shemshak Group mainly composed of siliciclastics rock overlies unconformably the older tectonostratigraphic units. The Shemshak Group within the Alborz contains key information about the closure of the Paleotethys Ocean, the rise and denudation of the Cimmeride Mountains, and the opening of the South Caspian basin (Wilmsen et al., 2009).

The foreland basin was formed in Late Triassic time in response to ongoing convergence between Central Iran and Turan Plates. This event led to collision and transformation of the passive margin of the Alborz region into a peripheral foreland basin (Fursich et al., 2009b; Wilmsen et al., 2009) (Fig. 5- a). Forebulge domain of this foreland basin may be characterized by extensional faults and volcanic rocks within basal part of the Shemshak Group (Zanchi et al., 2009). The extension-related structures were inverted into compressional or strike-slip faults during the Meso-Cenozoic (Zanchi et al., 2006).

Detailed lithostratigraphic investigation (Fursich et al., 2009a) indicate that the Upper Triassic part of the Shemshak Group including Ekrsar, Laleh band and Kalaris Formations represents synorogenic deposits of the peripheral foreland basin which formed at initial stage of the Paleotethys collision and development of the Eo-Cimmerian unconformity.

Rapid Cimmerian uplift in front of the Turan plate resulted in significant change in sedimentary condition in Alborz foreland basin during Triassic- Jurassic boundary. Lowermost Jurassic molasse-type sediments (Javaherdeh and Alasht formations) overlie flysch-type Upper Triassic deposits by an angular unconformity. This unconformity is marked between conglomerates of the Javaherdeh and coarse arkosic sandstones of the lower Alasht Formations (Fursich et al., 2009a; Wilmsen et al., 2009).

#### 4- 5. Shemshak back arc rift basin

At the end of Lower Jurassic time, increasing of the subsidence rates in the southern Alborz indicate extension in northern Iran. This extension is related to the Neotethys subduction and the opening of a back-arc-rift basins more-or-less along the Paleotethys suture within Eurasian margin (Stampfli and Borel, 2002; Brunet et al., 2003; Golonka, 2004; Wilmsen et al., 2009)(Fig. 5- b)

The basal part of this basin may characterized by the evaporate sediments and volcanic activities in Sari and south of Damavand regions. In the Sari region, an 80 m thick succession of mudstones, gypsum, dolomites and lateritic

beds overlie the Elikah Formation. This evaporitic unit is followed by about 200 m of andesitic-basaltic volcanics and then by the siliciclastic rocks of Shemshak Group (Vahdati-Daneshmand and Saidi, 1991).

This basin were later filled with Upper part of Shemshak Group in the southern Alborz containing Toarcian Shirindasht Formation overlain by about 500 m of deep marine shales of the Aalenian to lowermost Bajocian Fillzamin Formation and covered by Lower Bajocian deltaic sediments of the Dansirit Formation (Fursich et al., 2009a).

#### 4- 6. South Caspian carbonate platform basin

From Middle Jurassic time the siliciclastic deposits of the Shemshak Group was replaced by a carbonate system of Dalichai and Lar Formations covered parts of the Alborz region. This transformation in sedimentary condition resulted from new stage of a rapid subsidence following the Mid-Cimmerian event (Wilmsen et al., 2009). Crustal extension may be responsible for the great magnitude of the relative deepening and rotated fault

blocks (Fursich et al., 2009b). This event of increased back-arc-rifting represents the formation of the South Caspian Basin in southern part of Turan plate (Fig. 5- c). Rifting phase of the basin started in the late Early Jurassic and sea-floor spreading was established by the Late Bajocian and the sedimentation continued into Cretaceous time in a shallow marine condition (Zanchi et al., 2006). From stratigraphic point of view, Mid Cimmerian unconformity between Dansirit and Dalichai Formation can be considered as a sedimentary indicator which reflect onset of sea-floor spreading in the South Caspian Basin to the north (Wilmsen et al., 2009; Fursich et al., 2009b). Dalichi and Lar Formations as well as Cretaceous carbonate are supposed to be deposited as carbonate platform sediment on the southern part of the south Caspian basin. The age of the oldest sediments of the South Caspian Basin is unknown and the thickest series is represented by a 10 km of Pliocene–Quaternary sediments deposited on the remnant of this basin (Caspian Sea) during 5 Ma (Brunet et al., 2009).

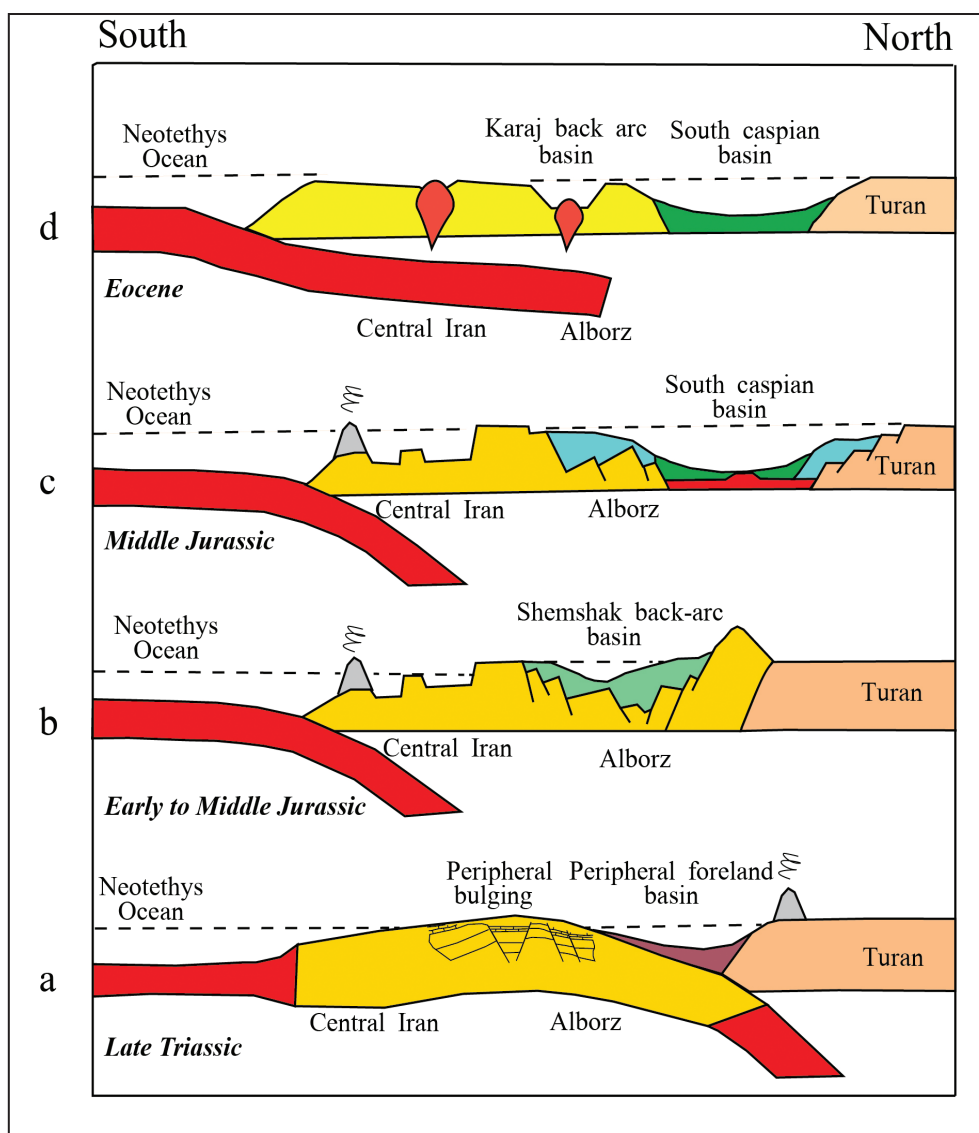


Fig. 5- Evolution of tectonosedimentary basin in Central Alborz from Late Triassic to Eocene times. Modified after Wilmsen et al. (2009). See text for detail.

#### 4- 7. Paleocene clastic sedimentary basin

A Late Cretaceous to Paleocene compressional event in the Alborz is represented by folding of Middle Jurassic-Cretaceous carbonate platform (Zanchi et al., 2006; Guest et al., 2006). The Cretaceous carbonates are then overlain above an angular unconformity by the Paleocene conglomerates of Fajan Formation (Dellenbach, 1964; Stocklin, 1971). This event resulted in exhumation and cooling pulse associated with folding in the south Central Alborz which closed the carbonate platform basins in the southern part of south Caspian basin (Fig. 6) (Guest et al., 2006; Ehteshami Moinabadi et al., 2012). From this time the submarine sedimentation was continued in the south Caspian basin in north area of Alborz.

#### 4- 8. Karaj back arc basin

During Eocene time, strong extension associated with normal faulting developed a large basin with the thick volcanoclastic deposits of the Karaj Formation in the southern part of the Central Alborz as well as Talesh Azerbaijan regions (Brunet et al., 2007; Fig. 5-d). The Eocene volcanic and volcanoclastic rocks of the Karaj Formation containing more than 3000 m thick of andesitic and andesite basalt lava flow, tuff and agglomerate. The formation of this sedimentary basin is related to the growth of an intracontinental volcanic arc in an extensional back arc setting related to the last phases of the Neotethys subduction along the Zagros suture zone (Alavi, 1996; Shahidi, 2008). This volcanic rocks arc resulted in change of Neotethys subduction angle and migration of magmatism and intracontinental orogeny towards the Alborz in north of Iran (Verdel et al., 2011). During the Neogene period this basin started to close in response to the collision between Arabia and Eurasia, leading to the main mountain building period in Alborz and adjacent area (Egan et al., 2009).

#### 4- 9. Oligo-Miocene foreland basin

The Neogene successions show different facies and thickness, including continental deposits in the Talesh area and shallow-sea coastal fine-grained terrigenous bodies with gypsum layers and bioclastic limestones in southern central Alborz. These basins possibly formed in a foreland basin developed at the front of the growing Alborz belt (Zanchi et al., 2009).

This uplift is a regional event which occurred simultaneously in Caucasus, Talesh, and Koppeh Dagh areas surrounding the south Caspian basin. The erosional materials of the uplift provided an important source of sediment, filling up the subsiding South Caspian Basin and the foreland basins of the Central Alborz Mountains (Brunet et al., 2009).

#### 4- 10. Pliocene-Pleistocene intramontane basin

Late Alpine event resulted in uplift of the entire Alborz region and formation of the discontinuous intramontane basins filled with Hezardareh Formation. The Hezardareh Formation composed mainly of conglomerates, with minor intercalations of sandstones and mudstones. It was folded in the Late Pliocene- Pleistocene time and then was uncomfortably overlain by subhorizontal, alluvial of Quaternary Kahrizak Formation. This Formation covered the foothills of the southern Alborz along its entire length (Rieben, 1966).

#### 5- Conclusion

Review of the tectonics and sedimentary investigations in the Central Alborz region, as examined in this paper, indicates that the sedimentary basins were formed in 10 different tectonic setting from Neoproterozoic to recent time.

Shallow water sediment of Kahar, Soltanieh, Lalun, Zagun and Mila formation supposed to be deposited in an epicontinental/platform basin within Prototethys passive margin. This succession is fragmented by a rift-related magmatic event and associated sedimentation during Ordovician to Devonian time. Shallow marine carbonates sediments and basaltic lava flows of Jeirud, Mobarak, Dorud, Ruteh, Nessen and Elikah Formations were deposited in Devonian to Middle Triassic continental shelf basin in the marginal part of the Paleotethys Ocean. A drastic change in sedimentary basin is marked in Shemshak Group deposited following of the Lower-Middle Triassic platform carbonates of the Elikah Formation. This group which originated from a peripheral foreland basin was mainly deposited in a back arc basin related to subduction of Neotethys beneath the central Iran. This back arc basin transformed to South Caspian basin in Middle Jurassic time. The Delichai, Lar and Cretaceous carbonate were deposited within carbonate platform basin in the south of the newly burned south Caspian basin. This basin was later closed due to the Late Cretaceous to Paleocene compressional event and formation of clastic basin of Fajan Formation. During Eocene time final stage of subduction resulted in formation of second back arc basin which established by sedimentation of volcanosedimentary rocks of Karaj Formation. This basin was inverted by Late Eocene-early Miocene compressional event. This event led regional uplift, and marine regression and finally resulted in the formation of erosional cycles and rapid filling of the Alborz foreland and intramontane basins with piedmont and alluvial sediments.

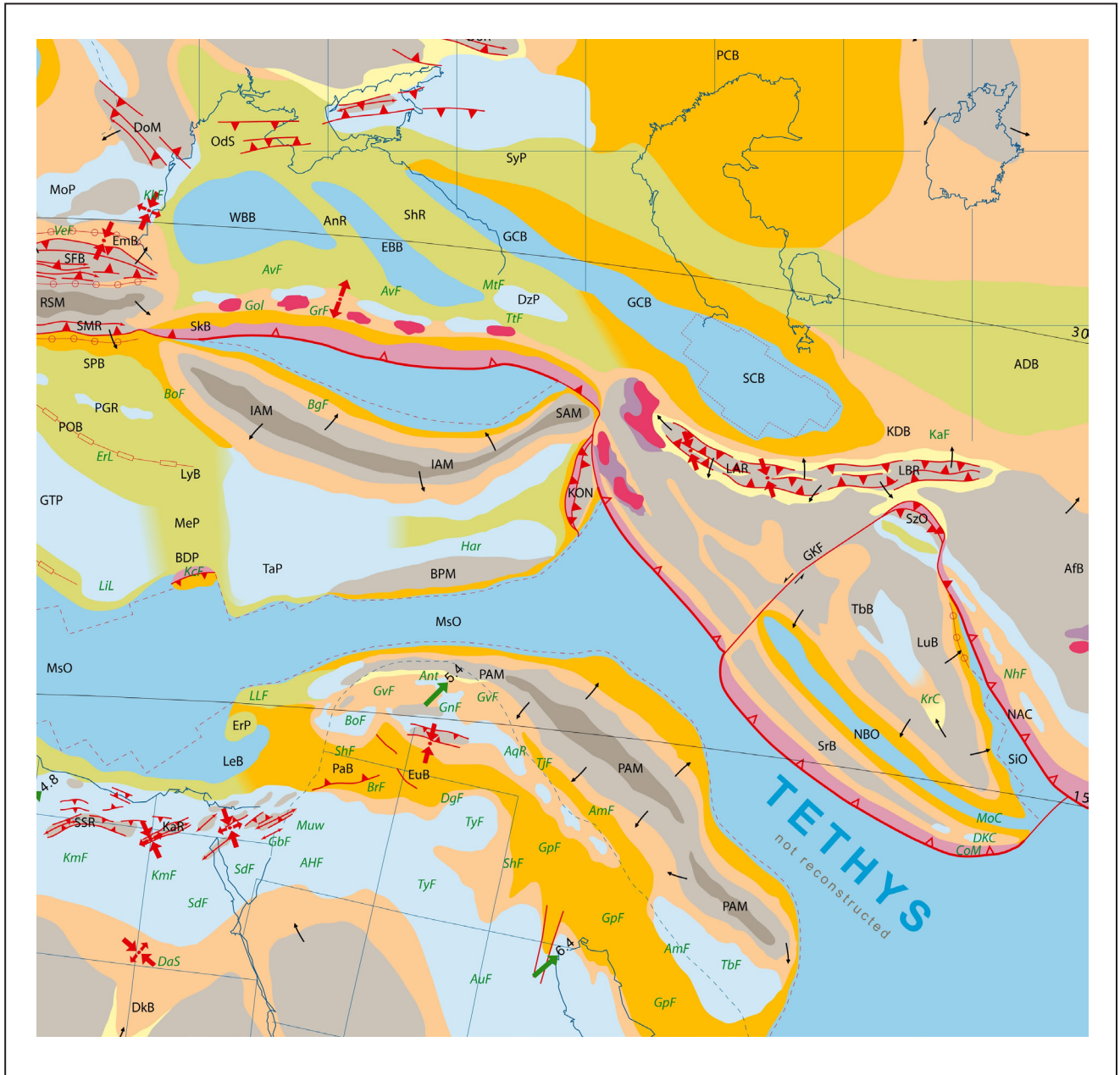


Fig. 6- Paleogeographic map of tectonic fragments and different basins in part of the Middle East in Late Cretaceous- Early Paleocene time. Closure of platform basin in southern part of the South Caspian Basin (SCB) is shown. After Barrier and Vrielynck (2009)



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