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# Oligocene stratigraphy of the Northern Subcoastal Fars Zone (Tang-e-Khoshk, Zagros structures, Iran): Biostratigraphy and Paleoenvironment

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**ABSTRACT**

**Objective:** The Asmari Formation is characterised by alternation thick carbonate and marl sequence of the Oligocene- Miocene in the Zagros Basin, southwest of Iran that were deposited on the shelf of Eastern Paratethys. **Methods:** This formation is exposed at Tang-e-Khoshk in the Fars subcoastal zone with a thickness of 286 m comprising alternation of medium and thick to massive bedded carbonates, marlylimestone and marl. The age of the Asmari Formation in the study area is the Oligocene (Ruplian&Chattian). **Results:** Ten microfacies are defined, characterizing a gradual shallowing upward trend; the related environments are as follows: open marine (MF1, 2&3), shoal (MF4) and lagoon (MF5, 6&7). A carbonate ramp platform is suggested for the depositional environment of the Asmari Formation. MF 1, 2, 3 &4 are characterized by the occurrence of large and small foraminifera representing a represent a deeper fair weather wave base of a middle ramp setting. MF 5, 6& 7 with large particles of different bioclast debis and algae, shallow-water setting of an inner ramp.

## 1.Introduction

The Oligocene-Miocene Asmari Formation (James and Wynd, 1965) consists mainly of carbonate sequence and crops out in the High Zagros and Zagros Simple Fold Belt of the Zagros Mountains in southwest Iran (Zagros subdivision is according to Berberian, 1981) (Fig. 1A). Some sandstone layers (the Ahvaz Member) and anhydrite deposits (the Kalhur Member) are also present. The Kalhur evaporite deposits in the Lurestan Province and Ahvaz sandstone deposits in southwest Dezful Embayment are two members of the Asmari Formation, but the Ahvaz and Kalhur members are absent in this columnar section. The Asmari Formation (Euphrates Formation in Iraq) contains some of the largest oil reservoirs in the world (Alavi, 2004). Previous studies on subsurface data and outcrops of the Asmari Formation were carried out by Adams and Bourgeois (1967), Wells (1967), Seyrafian (1981), Kalantari (1986) , Jalali (1987), Seyrafian et al. (1996), Hamedani et al. (1997), Seyrafian (2000), Seyrafian and Hamedani (1998, 2003), Nadjafi et al. (2004), Seyrafian and Mojikhalifeh (2005), Vaziri-Moghaddam et al. (2006), Amirshahkarami et al. (2007a, 2007b), Ehrenberg et al. (2007), Hakimzadeh and Seyrafian (2008), Sadeghi et al. (2009 and 2010), Mossadegh et al. (2009), Laursen et al. (2009), and Sahraeyan et al. (2013) reviewed the stratigraphy, sedimentary facies, lithological characteristics and

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microfaunal assemblages of the Asmari Formation. The objective of this study is to describe biostratigraphy, facies analysis and sedimentary environments surface Tang-e-khoshk sections (Tamar anticline) (Fig. 1B).

## 2.Regional setting

Cenozoic carbonate rocks are a fundamental link between modern depositional environments and those of the older stratigraphic record (Rahmani et al., 2009). The Asmari Formation was deposited in a northwest-southwest oriented foreland Zagros Basin which extended from northeastern Syria through northern and northeastern Iraq into southwestern Iran (Fig6B). The Tamar Anticline (Tang-e-khoshk section) is located in Fars Salient (sobcoastal fars) in the south of Zagros Fold-Thrust Belt (ZFTB) (Fig. 1A&B). The ZFTB includes a heterogeneous sequence of the latest Neoproterozoic–Phanerozoic sedimentary cover strata, about 7–12 km thick (Alavi, 2007). The ZFTB is the deformed state of the Zagros Basin that is extended over the northeastern Afro-Arabian continental margin and is affected by the Early Cretaceous to present Zagros Orogeny (Fig6A&B). On the basis of lateral facies variations, the Zagros Fold-Thrust Belt is divided into different tectonostratigraphic domains that from NW to SE are: the Lurestan Province or Western Zagros, the Izeh Zone and Dezful Embayment or Central Zagros, and finally Fars Province or Eastern Zagros (Motiei, 1994) (Fig. 1B). In the southwestern part of the Zagros basin, the Asmari Formation overlies the Pabdeh Formation, whereas in the Fars and Lurestan regions it covers the Jahrum and Shahbazan formations. Although the lower part of the Asmari Formation interfingers with the Pabdeh Formation in the Dezful Embayment (Motiei, 1993), its upper part covers the entire Zagros basin. For instance, toward the coastal Fars area, it is mainly Rupelian while in the Dezful Embayment; it ranges from Rupelian to Chattian (Motiei, 2001). The top of the Asmari Formation, mostly Burdigalian in age, remains constant, but toward the coastal and interior Fars, it is Chattian. The study area (Tang-e-khoshk) is located in the northwestern part of the subcoastal Fars Interio Zone (Fig. 1). The study area is located about 35 km northwest Sepidan and about 35 km southeast yasuj city (Fig. 1C).

## 3. Methodology and Lithology

This study is based on the field and laboratory investigation of the lower part of the Asmari Formation in the Zagros region of southwest Iran. One outcrop sections (Fig. 2A) were studied to determine the facies types, depositional environments, and Biostratigraphy. More than 200 samples were collected for petrographic studies to enhance the field descriptions. The sections were described in the field, including their weathering profiles, facies and bedding surfaces. Foraminiferal biostratigraphy in all thin-sections were analyzed under the microscope for biostratigraphy and facies. The biostratigraphy were Asmari Formation described according to the schemes porposed by Wynd (1965) and reviewed by Adams and Bourgeois (1967) and by Laursen et al. (2009). The lithology and the microfacies types were described according to the schemes porposed by Dunham (1962) and Embry and Klovan (1971). Facies definition was based on the microfacies characteristics, including depositional texture, grain size, grain composition, and fossil content (Flugel, 2010). The Asmari Formation in the study area in Tang-e-Khoshk, the thickness of the Asmari Formation is 286 m. It is composed of thin to massive bedded limestone with alternation of marly limestone and marl (Fig2A). The lower boundary of the Asmari Formation is exposed and underlain by the Pabdeh Formation and the upper boundary is exposed and overlain by the Razak Formation (both conformity )(Fig. 2B&C).

## 4. Biostratigraphy

Laursen et al. (2009) have established a new biozonation for the Asmari Formation (Fig 3). Based on this biozonation, the sediments ascribed to the Miocene (Aquitanian) are in fact Late Oligocene, Chattian in age. This was proved by the application of strontium isotope stratigraphy. From base to top, four foraminiferal assemblages were determined in the study area (Fig 3). In the study area, the age of the Asmari Formation is Oligocene (Ruplian&Chattian).Two assemblages of foraminifera were recognized in the studied areas and were discussed in ascending stratigraphic order as follows:

### 4.1. Assemblage 1

From the base upward to 212 m. Assemblage zone mainly consists of Globigerina sp., Nummulites vascus – Nummulites fichteli, Archaias sp., Nummulites sp. + Nummulites intermedius + Lepidocyclina sp. + Eulepidina sp. + Eulepidina elephantina + Eulepidiua dilatata + Operculina sp. + Operculina complanata + Heterostegina sp. + Heterostegina costata + Heterostegina cf. assilinoides + Neorotalia sp. + Neorotalia viennotti + Amphistegina sp.+ Amphistegina cf. bohdanowiczi + Elphidium sp. + Elphidium sp. 1 + Elphidium sp. 14 + Reussella sp. + Sphaerogypsina cf. globulosa + Neoplanorbulinella sp. + Discorbis sp. + Discorbis sp. 2 + Miliolids + Quinqueloculina sp. + Triloculina trigonula + Pyrgo sp. + Dendritina rangi + Peneroplis sp. + Peneroplis thomasi + Peneroplis evolutus + Archaias sp. + Archaias operculiniformis + Archaias asmaricus + Meandropsina sp. +Meandropsina anahensis + Meandropsina iranica + Austrotrillina sp. + Austrotrillina paucialveolata + Austrotrillina asmariensis + Austrotrillina howchini + Borelis sp. + Borelis pygmaea + Praerhapydionina delicata + Subterranophyllum thomasi + Tubucellaria sp. + Olssonina sp. + Onychocella sp. + Bigenerina sp. + Valvulinid sp. + Textularia sp. + Lithophyllum sp. + Lithothamnion sp. + Ostrea sp. + Balanus sp.. This assemblage corresponds to the Nummulites vascus- Nummulires Fichtelii assemblage zone of Laursen et al. (2009) (Fig. 3&5). The assemblage is considered to be Rupelian in age.

### 4.2. Assemblage 2

This assemblage zone which is 212 m thick, Nummulites sp. and Archaias sp. are present. Foraminifera of assemblage 2 include Neorotalia sp. + Neorotalia viennotti + Operculina sp. + Operculina complanata + Elphidium sp. + Elphidium sp. 1 + Elphidium sp. 14 + Amphistegina sp. + Amphistegina cf. bohdanowiczi + Neoplanorbulinella sp. + Reussella sp. + sp. +Spiroloculina sp. + Miliolids+ Quinqueloculina sp. + Triloculina trigonula + Discorbis Pyrgo sp. + Dendritina rangi + Peneroplis sp. + Peneroplis thomasi + Peneroplis evolutus + Borelis sp. + Borelis pygmaea + Austrotrillina asmariensis + Meandropsina sp. + Archaias sp. + Archaias kirkukensis + Valvulinid sp. + Textularia sp. + Bigenerina sp. + Lithophyllum sp. + Lithothamnion sp. + Ostrea sp. + Balanus sp. This faunal assemblage is correlated with Archaias asmaricus - A. hensoni - Miogypsinoides complanatus Assemblage Zone of Laursen et al. (2009) (Fig. 3&5). The assemblage is considered to be Chattian in age.

## 5. Facies analysis and sedimentary environments

The primary depositional features discernible in thin sections of the rock, including textures, microfossils and sedimentary structures, led to the recognition of 7 facies. These facies are related to five depositional settings (lagoon, shoal and shallow open marine) (Fig. 4&5) of carbonate ramp.

### 5.1. Shallow open-marine facies belt

#### 5.1.1. Planktonic Foraminifera Bioclast Wackestone (MF1)

This is the most widespread microfacies in the Asmari Formation succession of the Tang-e-khoshk section. It is mud-supported with foraminifers scattered within the cream colored except for gray colored carbonate rocks matrix. Allochems are mainly planktonic foraminifers and bivalves which are moderate to well preserved and filled with sparite. Less common skeletal constituents include bioclasts deriving from bryozoans, and echinoids (Fig. 4A&B). The general lack of sedimentary structures, the fine-grained matrix, and the presence of whole fossils of planktonic foraminifera suggest that this facies was deposited in calm and deep, normal-salinity seawater below the storm wave base with sporadic contribution of skeletal debris of benthic fauna (Wilson1975; Flügel 2010) (Fig. 6). This microfacies is equivalent to SMF 3 of Wilson (1975) and RMF 5 of Flügel (2010).

#### 5.1.2. Lepidocyclinidae Bioclastic Nummulitidae Packstone (MF2)

The constituents of this microfacies are nummulitid and Lepidocyclinidae (Nummulites and 40%) and alveolinid (Lepidocyclinidae, 15%) (Fig. 4C&D). Echinoderms, bryozoans and bivalve debris are also present. The Nummulites are well preserved, and the lack of abrasion of the Nummulites tests indicates that they were autochthonous accumulations, winnowed in situ by oscillatory current. This facies is most prominent in the lower parts of the Asmari Formation. The combination of micritic matrix and abundance of typical open-marine skeletal fauna including echinoids, large Nummulitidae, and Lepidocyclinidae suggest a low–medium energy, open-marine environment, and between the stormwave base and fair-weather wave base for deposition of this microfacies (Wilson 1975; Flügel, 2010). This facies was deposited in a low-medium energy, open marine environment. The dominance of corallinacean and large and flat nummulitids and lepidocyclinids with robust and lens shape tests in this facies, indicates deposition within the photic/oligophotic zone (Corda and Brandano 2003; Rasser et al. 2003&2005; Renema 2006; Bassi et al. 2007; Barattolo et al. 2007). The sediments with robust and lens specimens reflect shallow water than those containing larger and flat nummulitids and lepidocyclinids (Beavington-Penney and Racey 2004; Barattolo et al. 2007).

#### 5.1.3. Bioclastic Nummulitidae Packstone (MF3)

This microfacies is dominated by small lens-shaped *Nummulites* sp. (30%), and subordinate *opercolina* sp. which are often fragmented (Fig. 4E&F). Additional components are Miliolids debris, bivalves, gastropods, bryozoans and echinoderms. Fragmentation of larger foraminifera is common. The presence of the *Nummulites* and the Miliolids debris in the matrix indicate deposition well below the fair-weather wave base (FWWB). The presence of perforate foraminifera and echinoids, stratigraphic position below openmarine facies and the moderate sorted components in this facies suggest deposition in shallow open-marine environment. The grainy texture and the fragmented fauna suggest a relatively high-energy environment, probably near fair-weather wave base (Flügel 2010; Bassi et al. 2007; Rahmani et al. 2009). This microfacies is comparable to SMF 4 and RMF 15, 9 of Wilson (1975) and Flügel (2010), respectively.

### 5.2. Bioclastic Bar / Shoal facies belt

#### 5.2.1. Nummulitidae Miliolids Bioclast Packstone-Grainstone (MF4)

This microfacies is characterized by a high abundance of shell fragments (mainly Miliolids and Nummulitidae debris). Bioclasts of this microfacies belong to gastropods, bivalves, algae, benthic foraminifers and echinoderms (Fig.4G&H). Miliolids and red algae are dominant components of the microfacies. This facies has a packstone–grainstone texture. The features of these facies indicate moderate to high-energy shallow water conditions with significant movement and reworking of bioclasts. In accordance to the standard microfacies types described by Wilson (1975) and Flugel (2010), microfacies is interpreted as a shoal environment above the normal wave base which was located at the platform margin, separating the open-marine from the more marine environments. The associations of miliolids within this microfacies support the additional interpretation of a relatively protected environment, probably an inner part of a platform (Pomar, 2004). Moreover, scattered branching coral are characteristics of reduced water energy in the lowest part of the euphotic zone (Geel, 2000). However, the common coral debris may have derived from adjacent patch reefs or could also have been produced in situ from isolated colonies that are known. This microfacies is equivalent to SMF 12 of Wilson (1975) and RMF 27&28 of Flügel (2010).

### 5.3. Lagoon facies belt

#### 5.3.1. Neorotalia Bioclastic Imperforate Foraminifera Wackestone-Packstone (MF5)

This facies is composed of wackestone–packstone with micritic bioclastics. Skeletal grains include echinoid, Neorotalia, red algae, bivalve debris and miliolids (Fig. 4I&J). Romero et al., (2002), Rasser and Nebelsick (2003), Corda and Brandano (2003) and Vaziri-Moghaddam et al. (2006) considered the similar facies are representative of a shelf lagoon. Small to medium-sized nummulitids in association with smaller miliolids indicate that sedimentation took place in a shelf lagoon (Fig. 4I&J and 6). A similar facies with imperforated foraminifers, perforated foraminifers (operculina, heterostegina,) was reported from inner ramp of the Miocene sediments of the central Apennines (Corda and Brandano 2003) and from Early Oligocene deposits of the Lower Inn Valley (Nebelsick et al. 2001). Open lagoon shallow subtidal environments are characterised by microfacies types that include mixed open marine bioclasts and protected environment bioclasts.

#### 5.3.2. Miliolids Bioclast Wackestone-Packstone (MF6)

The main components grain of this microfacies are Miliolids and benthic foraminifera, fragments of macrofossils (Fig. 4K). Textures are dominantly packstone, but range from wackestone. Benthic foraminifers are common and include miliolids (Fig. 4K). Other common bioclasts constituents include bivalve fragments. Rare algae is also present. The grains are poorly to medium sorted, are fine to medium size and vary from sub-angular to semi-rounded. This microfacies represents the shallowest upper part of the photic zone, with very light, highly translucent and soft muddy substrate (Vaziri-Moghaddam et al., (2006); Bassi et al., (2007)). This facies was deposited in a shelf lagoon.Concurrent of normal marine bioclasts and lagoonal suggest deposition at the lagoonal (Hallock and Glenn, 1986) and the textural characteristics and abundance of miliolids suggest that the sedimentary environment is a lagoon with a nearby tidal flat. This microfacies is equivalent to SMF 10&18 of Wilson (1975) and RMF 20 of Flügel (2010).

#### 5.33. Mudstone (MF7)

The main features of this microfacies are preserved traces of depositional textures, such as scattered detrital very fine-sized quartz grains, thin-bedding planes. This facies occurs in middle and upper parts of the Asmari Formation (Fig. 4L&5). Lime mudstone with fine-sized quartz grains in Facies with no evidence of subaerial exposure was deposited in within a micritic groundmass is typical of restricted inner lagoon environments. This facies indicates hypersaline conditions in an area of the shelf lagoon. The low biotic diversity of foraminifers indicates a high-stressed habitat in a very shallow restricted shelf lagoon. The general lack of sedimentary structures and the fine grained, suggest that facies was deposited in calm and deep, normal-salinity water (Cosovic et al 2004; Flugel 2010). This microfacies is equivalent to SMF 23 of Wilson (1975) and RMF 19 of Flügel (2010).

## 6. Palaeoenvironmental model

Due to their well-defined palaeoecological requirements, they represent valuable facies indicators (Rasser et al. 2005). The most important components of the studied carbonate sedimentary samples are larger foraminifera and nummulitids. The Asmari Formation represents sedimentation on a carbonate ramp with a very gentle slope, on the basis of the distribution of the biota, textures, stratigraphy, lithofacies and vertical facies relationships. The lack of any marginal reef development, absence of a major break in slope from shoreline into deeper water, and the presence of landward, high-energy grainstone facies are evidence that the Asmari Formation was deposited on a carbonate ramp (Fig. 6A&B and C). Carbonate ramp environments are characterized by: (1) the inner ramp, between the upper shoreface and fair weather wave base, (2) the inner ramp, between fair weather wave base and storm-wave base, and (3) the outer ramp, below normal storm-wave base down to the basin plain (Burchette et al. 1992) (Fig. 6A&B and C). Most carbonate sequences from the Asmari Formation were deposited in inner and middle ramp environments in the Tange-e-khoshk section.

## 7. Conclusions

In the study area, Asmari Formation is generally represented by Carbonate ramp, overlies the Pabdeh Formation conformably and is overlain by Razak Formation. In the study area, the thickness of the Asmari

Formation is 286 m. It is composed of thick to massive bedded limestone with intercalation of marl and alternation of limestone with marl. Based on the biostratigraphy of the Asmari Formation, age of this formation is Oligocene (Rupelian and Chattian)). Deposits of the Asmari Formation in the Tang-e-khoshk were deposited in a carbonate ramp similar to the Persian Gulf. Seven microfacies (Planktonic Foraminifera Bioclast Wackestone, Lepidocyclinidae Bioclastic Nummulitidae Packstone, Bioclastic Nummulitidae Packstone, Nummulitidae Miliolids Bioclast Packstone-Grainstone, Neorotalia Bioclastic Imperforate Foraminifera Wackestone-Packstone, Miliolids Bioclast Wackestone-Packstone and Mudstone), characterizing a gradual shallowing and depositional environments correspond to inner and middle ramp, were identified.

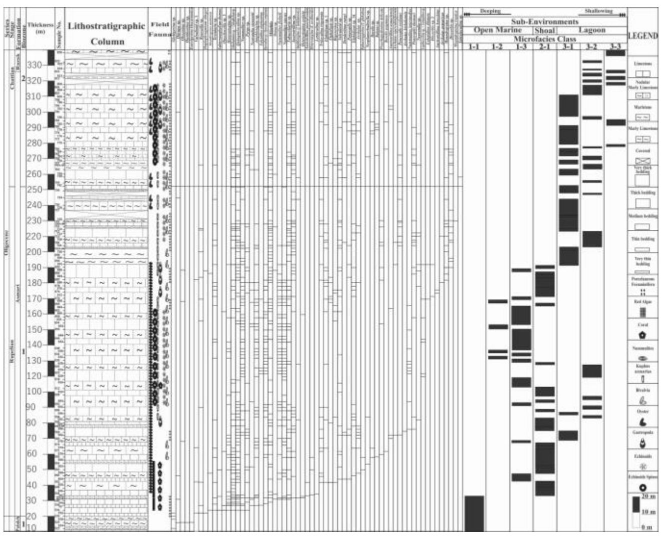


**Fig.1**: (1A) - Tectonic zones of Iran and location of the studied area (adopted from Heydari, 2008). (1B)- Subdivisions of the Zagros province and Location of the Subcoastal fars zone in Zagros basin (adapted from Maghsoodi, 2002). (1C)- Simplified geological maps of the study areas with locations of the studied section. Sheet 1:100,000 of Ardakan by (adapted from McQuillan, 1978).

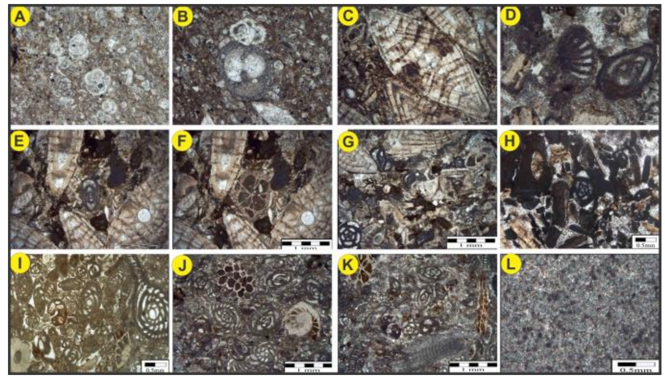


**Fig.2:** General view of the studied section (2A), lower boundary of Asmari Formation with Pabdeh Formation (2B) and (2C) upper boundary of Asmari Formation with Razak Formation.

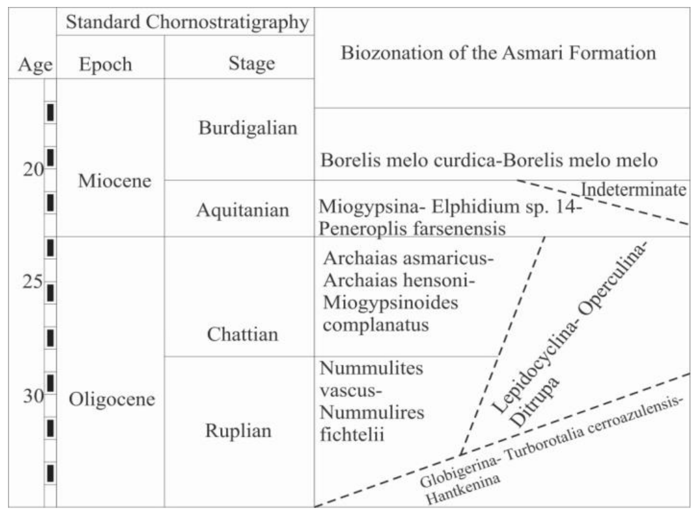
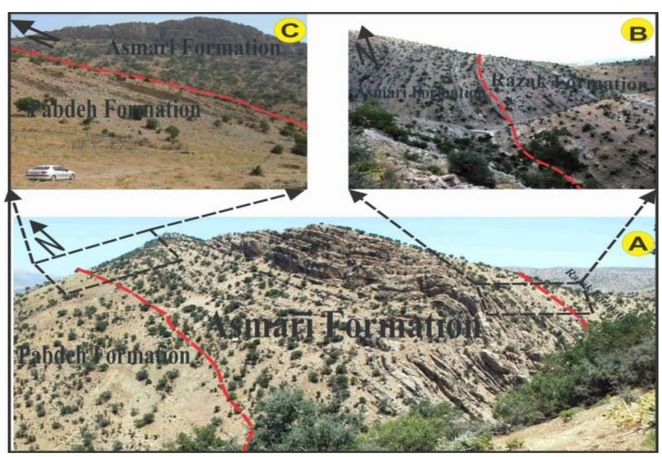



**Fig.3:** Biozonation of the Asmari Formation, after Laursen et al. (2009).




**Figs.4:** Microfacies (4A) and (4B) Planktonic Foraminifera Bioclast Wackestone (MF1): (4C&4D) Lepidocyclinidae Bioclastic Nummulitidae Packstone (MF2): (4E &4F) Bioclastic Nummulitidae Packstone (MF3): (4G&4H) Nummulitidae Miliolids Bioclast Packstone-Grainstone (MF4): (4I&4J) Neorotalia Bioclastic Imperforate Foraminifera Wackestone-

Packstone Bioclast, (MF5): (4K) Miliolids Bioclast Wackestone-Packstone (MF6): (4L) Mudstone (MF7).

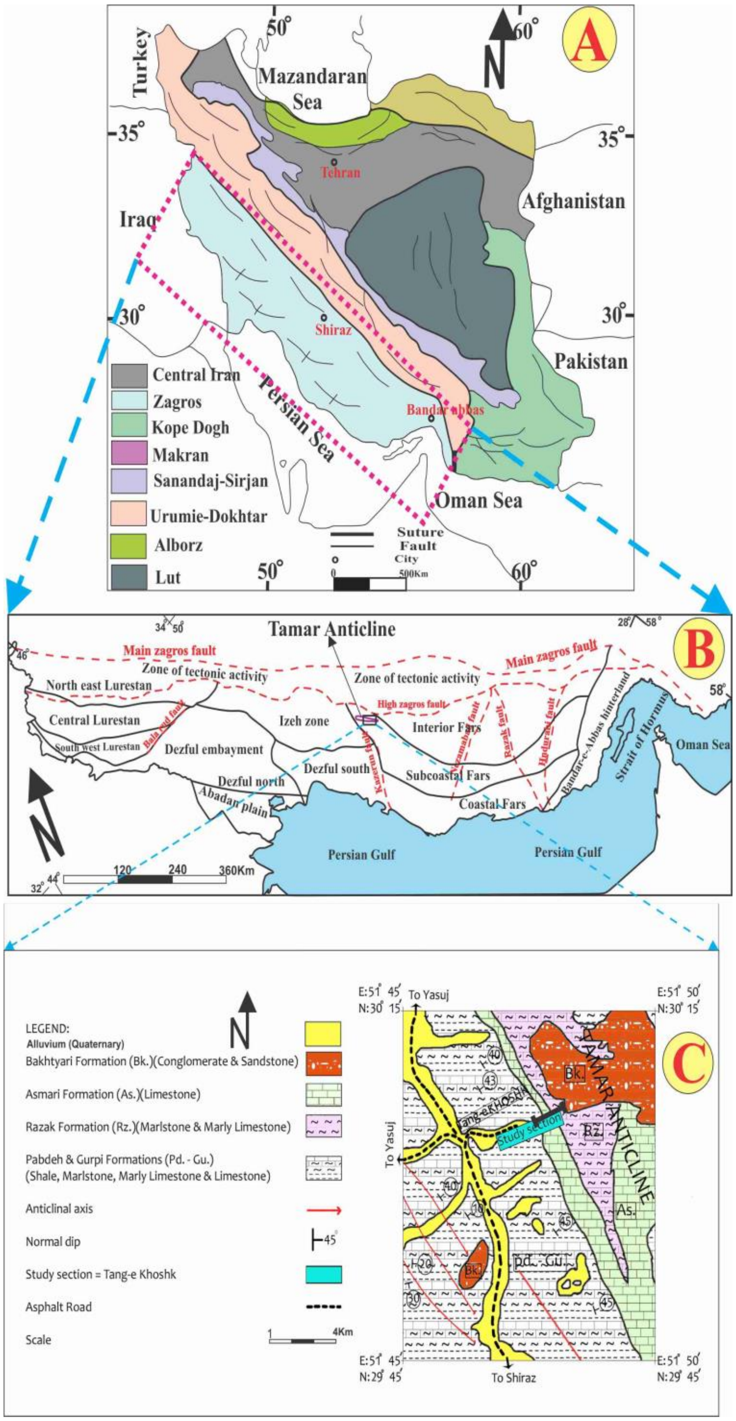
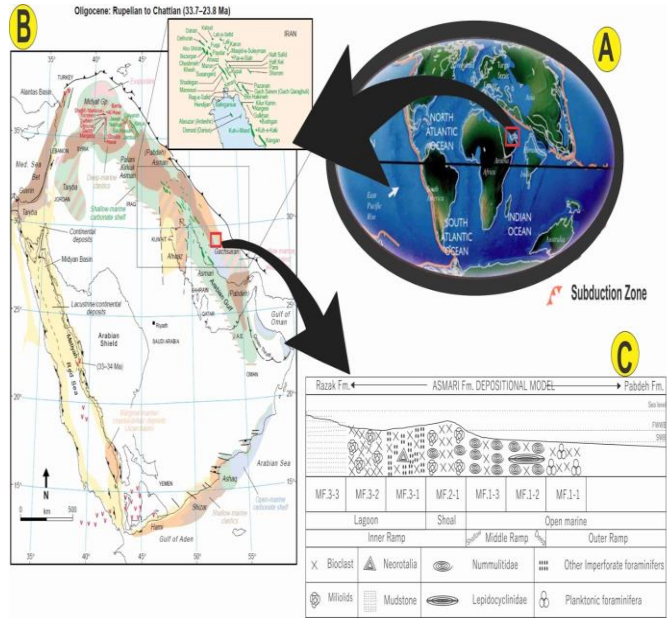



**Fig.5:** Microfacies, Lithostratigraphic column and vertical distribution of major foraminiferal biozonation sequences of the Asmari Formation at Tang-e-khoshk section, Zagros.




Figs. 6- (6A) Paleogeographic reconstruction showing simplified plate boundaries and Iran location of Plate Arabian (Paleogene: 50 Ma) (James G. et al. 2008). (6B) Close-up view of red square fig A. Paleo-tectonic, Paleogeographic and lithology map of the Arabin plates during the Oligocene (Rupelian to Chattian: 33.7-23.8Ma) (Zigler, 2001). (6C) Schematic block diagram for depositional model of the Asmari Formation in the study area with available allochem in facies belt.

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