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Depositional setting of the Lower Miocene Qom Formation deposits from the northwest of Iran Central Basin

İran Merkez Havzası'nın kuzeybatısındaki Alt Miyosen Qom Formasyonu çökellerinin çökelme ortamı

HAMIDEH NOROOZPOUR[1*]

[1] Department of Geology,Faculty of Science, Payame Noor University (PNU), Tehran, Iran

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ABSTRACT

An outcrop of the Qom Formation (Fm.) is considered to determine the depositional setting model in the northwest of Central Iran. Field observations show that the Qom Fm. is composed of thin to thick-beds limestone along with alternation of green marl and argillaceous limestone. Based on the stratigraphic distribution of foraminifera, Borelismelocurdica-Borelismelomelo Assemblage Zone has been recognized in the Qom Fm.. Consequently, the Burdigalian in age is offered for the Qom deposits. A careful study of the characteristics of biological facies and sedimentary textures is specified eight facies types concerning the four facies belts of the lagoon, reef, slope, and open marine. Lacking in the sediment gravity flows and turbidity facies, and high abundance of reef facies (25 percent of Qom deposits) including coral boundstone, algae, and bryozoans, reflect likely a deposition on an open shelf. Facies distribution shows that the Qom Fm. sedimentation had begun in the continental slope depositional setting during Aquitanian? without considering the possible erosion processes. However vigorous sea level fluctuations had occurred during Aquitanian-Burdigalian. Hence, active tectonic can be proposed for study area during Early Miocene.

Keywords: Facies, depositional setting, Qom, Burdigalian, Central Iran.

ÖZ

Orta İran'ın kuzeybatısındaki çökelme ortam modelini belirlemek için Qom Formasyonu'na (Fm.) ait bir yüzlek incelenmiştir. Saha gözlemleri, Qom Formasyonu'nun ince-kalın tabakalı kireçtaşları ile yeşil marn ve killi kireçtaşı ardalanmasından oluştuğunu göstermektedir. Foraminiferlerin stratigrafik dağılımına dayanılarak, Qom Fm. dahilinde Borelismelocurdica-Borelismelomelo Bolluk Zonu tanımlanmıştır. Sonuç olarak, Qom çökelleri için Burdigaliyen yaşı önerilmiştir. Biyolojik fasiyesler ve tortul dokuların özelliklerinin incelenmesi ile, *lagün, resif, yamacı ve açık deniz ortamlarının dört fasiyes kuşağı ile ilgili sekiz fasiyes tipi belirlenmiştir. Sediman gravite akışları ve türbiditik fasiyeslerin eksikliği ve mercanlı bağlamtaşı, algler ve bryozoanlardan oluşan resif fasiyeslerinin bolluğu (Qom çökellerinin yüzde 25'i), muhtemel bir açık şelf ortamında çökelimi yansıtmaktadır. Muhtemel erozyon süreçleri dikkate alınmadığında fasiyes dağılımı, Qom Fm. tortullaşmasının Akitaniyen? sırasında kıtasal yamaç çökelme ortamında başladığını göstermektedir. Ancak Akitaniyen-Burdigaliyen döneminde belirgin deniz seviyesi değişimleri meydana gelmiştir. Bu nedenle çalışma alanı için Erken Miyosen sırasında aktif tektonik önerilebilir.*

Anahtar Kelimeler: *Fasiyes, çökelme ortamı, Qom, Burdigaliyen, Orta İran.*

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* Corresponding Author/ Sorumlu Yazar: Hamideh Noroozpour

INTRODUCTION

The Qom Fm. has a wide distribution in the Central Iran basin and extends from northwest to southeast of Iran. In this study, the biofacies analysis and depositional setting will be addressed in the stratigraphic section located at Goylar village (36°57'20.09"N, 47°50'26.19"E), 100 km southwest of Zanjan city. The Qom Fm. studies in the Central Iran basin began by Loftus (1855) and Tietze (1875). The marine Qom Fm. deposited in the Oligo-Miocene during the final marine transgression in the Sanandaj-Sirjan fore-arc basin, Urumieh-Dokhtar magmatic arc (Intra-arc) basin and Central Iran back-arc basin (Furrer and Soder, 1955; Abaie et al., 1964; Bozorgnia 1966; Okhravi and Amini, 1998; Schuster and Wielandt, 1999; Daneshian and Ramezani Dana, 2007, Mohammadi and Ameri, 2015, Mohammadi et al.,2019, and Mohammadi, 2020). Furrer and Soder (1955) divided the Qom basin into six members (a to f; a: basal limestone, b: sandy marls, c: alternation of marls and limestone, d: evaporites, e: green marls and f: limestone). Abaie et al. (1964) subdivided the Qom Fm. into ten members in a type section, from the Chattian to the Burdigalian time interval. Bozorgnia (1966) identified nine members from Rupelian to Burdigalian (a, b, c1, c2, c3, c4, d, e, and f). Eventually, this division (Bozorgnia, 1966) was accepted by the Iranian stratigraphic committee. Because of the concentration of hydrocarbon resources within the Qom succession, in the last decade, more studies have been done on the Qom Fm. in the many different regions of Iran.

So far, few studies have been undertaken on the "f" member of the Qom Formation in the northwest of the structural basin of Central Iran, Hence, the main purpose of this research is to determine the relative age and a sedimentary model of the Qom Formation.

GEOLOGICAL SETTING

The Qom deposits of the Goylar stratigraphic section is located in the northwest of Central Iran structural Zone (Stöcklin and Setudehina, 1991) (Fig. 1). The Central Iran basin originated during the African / Arabian plate subduction system into the Iranian plate, and this process has been beginning during the Mesozoic. During the Early Paleogene, the Tethyan seaway was a wide ocean that connected the two major oceanic realms, the Atlantic, the Pacific and also the Indian oceans (Schustr and Wielandt, 1999). The subduction system and final collision of the African-Arabian plate around the Eocene-Oligocene boundary were accompanied by the vanishing of the Tethyan seaway, the disconnection of the

Atlantic and the Pacific oceans and the Mediterranean.

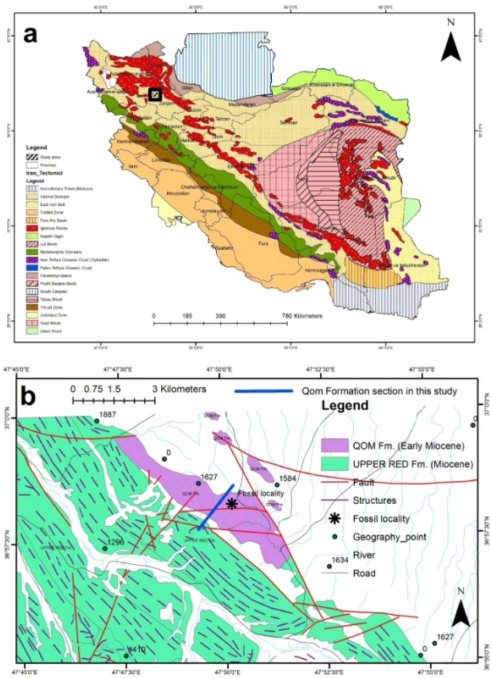

Fig. 1. a: The location of the study area on the structural basins map of Iran (modified from Stöcklin and Setudehina 1991); b: Geological map of the study area modified from Lotfi, 2002).

Şekil 1. *a: Çalışma alanının İran yapısal havzalar haritasındaki konumu (Stöcklin ve Setudehina 1991'den değiştirilerek); b: Lotfi, 2002'den değiştirilerek alınmış çalışma alanının jeolojik haritası.*

As a consequence, Central-Iranian paleogeography changed dramatically by the development of a volcanic arc which separated a forearc from a back-arc basin during Eocene times. Marine sedimentation of the Qom Fm. began during the Oligocene and continued to the end of the Early Miocene in the Esfahan-Sirjan forearc and the Qom back-arc basin (Schustr and Wielandt, 1999). In the study area, The volcanic rocks (basalts in unknown age) are located at the base of the Qom Fm. and the Upper Red Fm. (alternation of red marl, gypsum and sandstone; Miocene in age) is covered the Qom deposits in the Goylar section (Fig.2). Hence, in terms of stratigraphy, the surface boundaries at the base and the top of the Qom Fm. are disconformities. The Qom deposits (155 meters in thickness) at the base to the top in the Goylar section are including limestone, reef-coral limestone, and an alternation of green marl and argillaceous limestone. Also, a green to dark purple basaltic dyke intruded into the Qom deposits. According to the lithological aspects, the Qom Fm. in the Goylar section is equivalent to member "f".

RESULTS

In the following, the obtained results of biostratigraphic criteria, facies types, and depositional setting model of the Qom Fm. are addressed.

BIOSTRATIGRAPHY

The formal biozonation and biostratigraphy yet have not been proposed for the Qom Fm. in central Iran. Consequently, according to the significant similarity of the large benthic foraminifera between the Qom and the Asmari formations, palaeontologists compared these two. The biozonations established for the Qom Fm. were based on the biozonations of Wynd (1965) and Adams and Bourgeois (1967); However, during the last decade, most significant paleontological biozonation studies of the Qom Fm. have been introduced by Laursen et al., (2009) By undertaking paleontological study, a total of 19 genera and species of benthic foraminifera and 7 genera and 13 species of planktonic foraminifera are identified (Fig.3) in the Qom Fm., located at the Goylar section. These are as follows:

Borelis melocurdica, Psuedoilthonella richelli, Peneroplis evolutus, Peneroplis thomasi, Heterolepa dutemplei, Asterigerina rotula, Valvulina sp.1*, Valvulina* sp.2*, Pyrgo* sp.1.*, Amphistegina* spp.*, Spiroloculina* sp.*, Quinqueloculina* sp.*, Austrotrillina* sp.*, Miogypsina* sp., *Lenticulina sp., Elphidium sp.1., Rotalia* sp., *Nodosaria sp., Textularia* sp. *Globigerinoides primordius, Globigerinoides subquadratus, Globigerinoides trilobus, Globigerinoides immaturus, Paragloborotalia mayeri, Paragloborotalia* spp., *Globigerina praebulloides, Globigerina* sp., *Globigerinella obesa,Globorotaliaarcheomenardii,Globorotalia* sp., *Praeorbulina transitoria, Bolivina sp.*

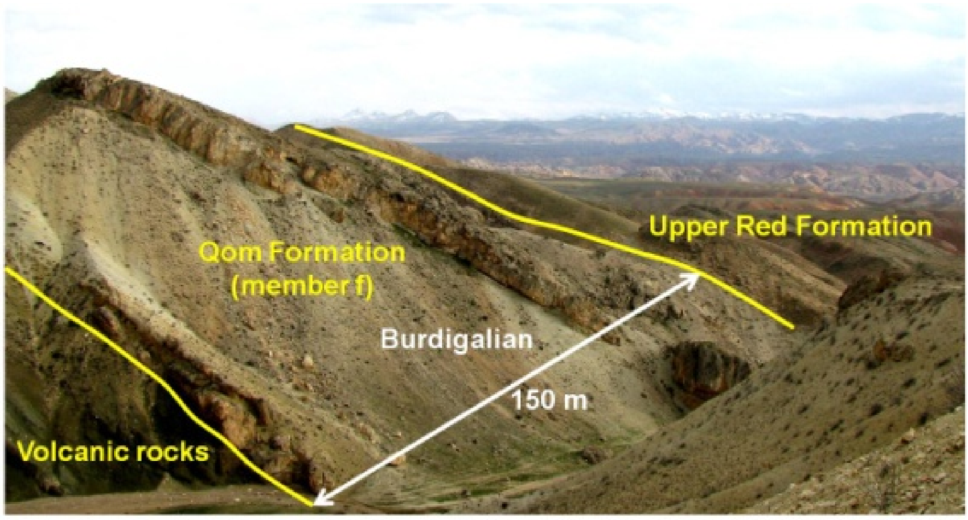

Fig. 2. The field-photograph from Goylar stratigraphic section, Look to the southeast.
Şekil 2. *Goylar stratigrafik kesitinin arazi görüntüsü. Bakış güneydoğuya.*

Based on the stratigraphic distribution of foraminifera, *Borelis melocurdica-Borelis melomelo* Assemblage Zone (150 meters in thickness) has been certainty recognized in the Qom Fm. as Burdigalian (Fig.4).The first appearance of *Borelis melocurdica* is identified in sample number-5 from the base of the Qom Fm. and extends upward about 150 meters. Hence, the deposits underlying five meters (0-5 meters) of the Qom Fm. are considered as Aquitanian-Burdigalian(?). The identified planktonic foraminifera confirm the Early Miocene in age. This biozone is equivalent to the *Borelis melocurdica* zone # 61(Wynd, 1965) and Zone- 1 as *Borelis melo* group - Meandropsina iranica Assemblage Zone described by Adams and Bourgeois (1967) in the Zagros Basin. It is also being equivalent to the *Borelis melocurdica-Miogypsina* zone (SB25) introduced by Cahuzac and Poignant(1997) in the southern European basins.

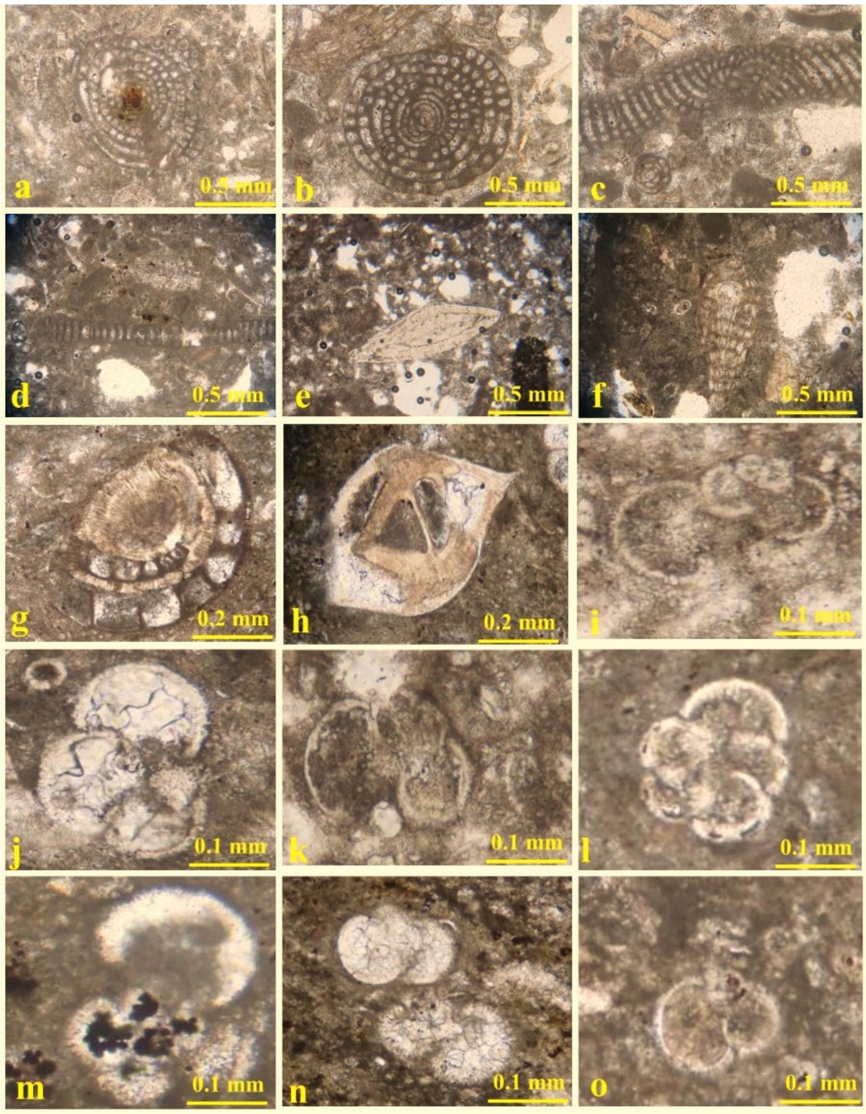

Fig. 3. Foraminifera microphotograph of the Qom Formation in this study. a & b: *Borelis melocurdica,* Equatorial section, c: *Peneroplis evolutus,* Axial section,d: *Peneroplis thomasi,* Axial section,e: *Amphistegina* sp., Axial section, f: *Miogypsina* sp.,Axial section, g: *Heterolopa dutemplei,* Equatorial section,h: *Lenticulina* sp., Axial section, i:*Globigerinoides triloba,* Axial section, j:*Globigerina praebulloides,* Equatorial section,k: *Globigerinoides primordius,* Axial section, l: *Paragloborotalia mayeri,* Equatorial section, m: *Globigerinella obesa,* Equatorial section, n: *Globigerinoides immaturus,* Axial section, o: *Praeorbulina transitoria,* Axial section.

Şekil 3. *Qom Formasyonu'nun Foraminifer mikrofotoğrafları. a & b: Borelis melocurdica, Ekvatoryal kesiti, c: Peneroplis evolutus, Aksiyal bölüm, d: Peneroplis thomasi, Aksiyal kesit, e: Amphistegina sp., Aksiyal bölüm, f: Miogypsina sp., Aksiyal bölüm, g: Heterolopa dutemplei, Ekvatoryal kesit,h: Lenticulina sp., Aksiyal kesit, i:Globigerinoides triloba, Aksiyal kesit, j:Globigerina praebulloides, Ekvatoryal kesit, k: Globigerinoides primordius, Aksiyel kesit, l: Paragloborotalia mayeri, Ekvatoryal kesit, m: Globigerinella obesa, n: Globigerinoides immaturus, Aksiyal kesit, o: Praeorbulina transitoria, Aksiyal kesit.*

FACIES

In terms of paleoenvironmental studies, the Qom Fm. has been introduced in wide facies types and different sedimentation models. For example, Reuteret al., (2009) in the Qom and Esfahan-Sirjan areas, Amirshahkarami and Karevan (2015) in the Qom province and Mohammadi et al., (2019) in the southwest of Kashan, had reported the sedimentary environment of the Qom Fm. as a carbonate ramp. Also, Mohammadi et al., (2011) in the west of the Ardestan area, Sedighi et al., (2011) in the northeast of Kashan, and Daneshian and Ramezani (2017) in the south of Garmsar had considered the sedimentary environment of the Qom Fm. as an open shelf. Changes in the rock texture and assessment of skeletal and non-skeletal components led to separating eight facies types for the Early Miocene Qom Fm. base on Read (1995) study.

MF1-Green marl

In this study, the green marl non-carbonate facies alternate with argillaceous limestone beds. The biotic components of this facies are composed mainly of planktonic foraminifera(*Globigerinoides,Paragloborotalia, Bolivina*,*Globigerina*,*Globorotalia*,*Praeorbulina*).The facies is equivalent to zone-2 documented by Read (1995) and SMF- 8-10 and 12, described by Flügel (2010). Bathymetric of Planktonic foraminifera are mainly based on their morphology (up to 50 meters) (Keller, 1999). Therefore, it can be expressed that planktonic foraminifera assemblages (49% of in total recorded in the Qom deposits) were lived in the open marine which there were conditions of aphotic zone, low salinity and water temperature (Flugel, 2004; Murray, 1973).

MF2-Planktonic Foraminifera wackestone - packstone

The main components are included planktonic foraminifera(*Globigerinoides,Paragloborotalia, Bolivina*, *Globigerina*, *Globorotalia*, *Praeorbulina*) (10-45 percent) along with benthic foraminifera such as *Nodosaria, Lenticulina and Heterolepa and*echinoid fragments within a homogenous micrite (Fig. 5 a, and b). This facies in geometry is a sheet form and macroscopically, it is fine grain argillaceous limestone. This facies includes about 44% of the Qom deposits in the Goylar section (Figs. 5 and 6).The facies is equivalent to SMF- 8-10 and 12, described by Flügel (2010). Mohammadi et al., (2019) documented similar facies from Qom Fm. and they believe that the facies probably deposited in the outer ramp.

Mf 3 - Bioclastic Miogypsina packstone

The facies contain benthic foraminifera (*Miogypsina*and*Amphistegina*) along with echinoids, red algae fragments and planktonic foraminifera within moderate sorting-coarse-grained packstone texture (Fig. 5 c). Macroscopically, it is cream in colour and thick-bed limestone. Small hyaline species in shell such as Amphistegina and Astrogerina are associated with the proximal parts of the open marine sedimentary environment with normal sea in salinity (Geel, 2000). The intergranular porosity is observed on the microscopic scale. Facies vertical distribution is very sparsely and comprises about 2% of Qom deposits (Figs. 6 and 7). Similar to this facies had considered by Daneshian and Ramezani (2017) in the Garmsar area/northern of Central Iran). The facies is equivalent to facies Zone-3 introduced by Read (1995) and SMF- 2,3 and 4, described by Flügel (2010).

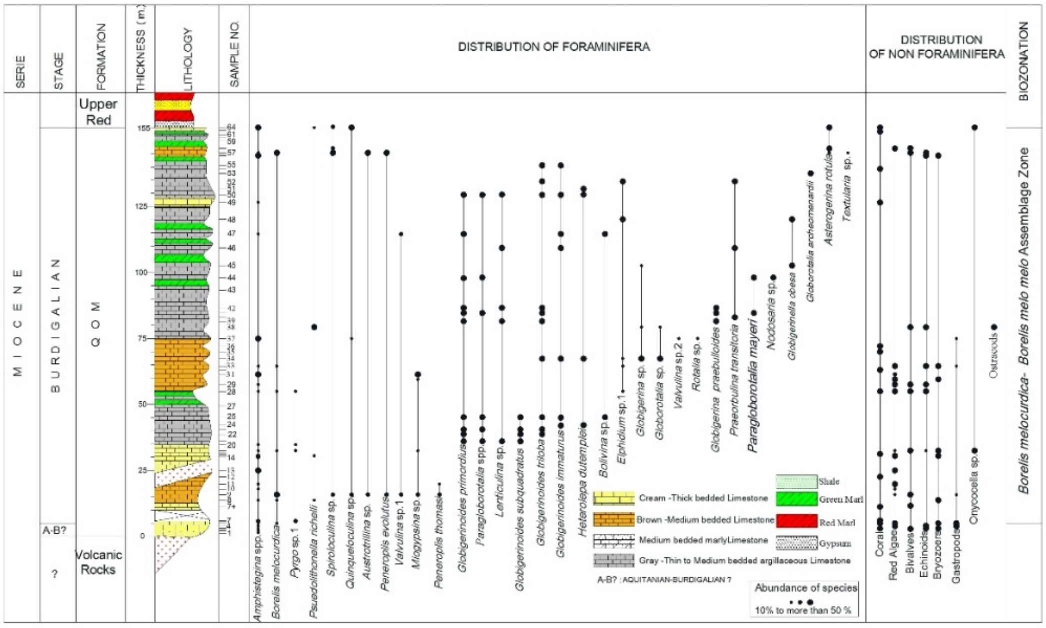

Fig. 4. Stratigraphic distribution of foraminifera and biozonation of the Qom Fm., Goylar Section; Abundance symbols indicate those species which are identified around 10% to more than 50% into a thin section.

Şekil 4. *Qom Formasyonu, Goylar Kesiti boyunca foraminifera stratigrafik dağılımı ve biyozonasyonu; Bolluk sembolleri, incekesitte %10 ile %50'den fazla olarak tanımlanan türleri gösterir.*

Mf 4–Amphistegina Coral Corallinacea Packstone

The biotic components of this facies are *Amphistegina*, coralline, corals, bryozoans and echinoids fragments (Fig 5 d). Petrographically, rounding and sorting are less developed generally within a packstone matrix and the intracellular and extracellularporosity is observed in this facies. Facies geometry is bedding form and macroscopically, it is thick layers of limestone in scale (up to 1.5 m). Facies vertical distribution in the Qom Fm. is amount 19.2 % in this study (Figs. 6 and 7).The facies is equivalent to facies Zone-4 introduced by Read (1995) and SMF- 4,5 and 6,described by Flügel (2010). Similar to this facies had introduced as a middle ramp environment by Mohammadi et al., (2019) in the south of Kashan and in the Natanz and Khoorabad regions (Mohammadi, 2020)

Mf 5–Coral Boundstone

The main allochems of the facies are an abundance of scleractinian coral colonies (more than 80%) that are mostly in their growth position along with red algae, bryozoans, bivalve bioclasts in boundstone frame. macroscopically, it is thick-bedded coral limestone (up to 2m) and observable in field observations (Fig 5 e). Coral colonies are continuous and traceable and are repeated several times along the succession. Facies vertical distribution in the Qom Fm. is amount seventeen percent (Figs. 6 and 7) in the Goylar section. The facies is equivalent to facies zone-5 reported by Read (1995) and SMF-7,11 and 12, described by Flügel (2010). Similar to this facies had been documented as a platform margin reef by Wilson (1975), Corado and Brandano (2003a), Nebelsick et al., (2005), and Brandano et al., (2009). Amirshahkarami & Karevan (2015) in the south of the Qom area, Mohammadi et al., (2019) in the south of Kashan and Mohammadi (2020) in the Natanz and Khoorabad regions had been introduced this facies as a distal inner ramp environment (patch reef).

Mf 6- Bioclastic bryozoanscorallinacean packstone

The main components include moderate sorting of the red algae (amount 30%) and bryozoans (15%) fragments along with bivalves, gastropods and echinoids within a packstone and sometimes in framestone textures (Fig 5 f). Petrographically, the inter-granular porosity is well developed in this facies. The facies is bedding form in geometry andmacroscopically it is light brown to cream, thick-bedded limestone.Facies consists of approximately seven percent of the Qom deposits in the Goylar Section (Figs. 6 and 7). The facies is equivalent to SMF-11-15 described by Flügel(2010).Similar to this facies had considered by Daneshian and Ramezani (2017) as a reef environment in the Garmsar area, northern of Central Iran.

MF7- Bioclastic Packstone

The main components are bivalves, red algae, ostracods, gastropods, and bryozoans along with some *miliolids* and echinoids fragments within a moderate sorting packstone texture (Fig 5 g and h). Non-skeletal fragments including well-rounded (good sorting) pellets are found in this facies. The facies geometry is bedding form and macroscopically it is cream in color, thick-bedded limestone (up to 2.2m). Similar to this facies has been considered by Daneshian and Ramezani (2017) in the Garmsar area/northern of Central Iran and comprise about seven percent of the Qom deposits (Figs. 6 and 7) in the Goylar Section. The facies is equivalent to SMF- 10 documented by Flügel (2010).

Mf 8- Porcelaneous foraminifera packstone

The facies contain porcelaneous foraminifera including *Borelis*, *Peneroplis*, *Austrotrillina, and Spiroloculina* along with echinoids, bivalves fragments, and with peloids (Fig 5i). Facies characterized by medium- to coarse-grained bioclastic packstone and subordinate wackestone containing poor to moderately sorted imperforate foraminifera embedded in a matrix of carbonate mud and microspar. Macroscopically, it is thick-bedded limestone (up to 1.8 m). Facies involves around 3.5 % of the Qom deposits (Figs. 6 and 7) in the Goylar Section. Accumulation of imperforate foraminifera develops in meso to oligotrophic settings at shallow depths and illustrates the sedimentation that took place under low- to moderate-energy conditions in the restricted lagoon from a platform interior environment (Photic zone) (Facies Zone-8 by Read, 1995). The facies is equivalent to the SMF -10 documented by Flügel (2010).

DISCUSSION

Interpratation and depositional setting model

Identified microfacies in the Goylar section along with association and distribution of perforate and imperforate foraminifera are the significant agents to the interpretation of the depositional setting model. Benthic foraminifera is an important indicator for paleoecological and consequently paleoenvironmental recognition of the Cenozoic carbonate platforms. Size, degree of flatness, and wall of the larger foraminifera test, provide valuable environmental inFm. (Hallock and Glenn, 1986; Geel, 2000; Mohammadi, 2020). The biotic community determines accumulation rate and facies zonations, thus controlling platform geometry (Mutti and Hallock, 2003; Brandano et al., 2009a).

As explained, facies analysis introduced eight microfacies related to the four major facies belts as lagoon, reef, slope, and open marine. Distal open marine environment is characterized by Mf1 as green marl and Mf2 as Planktonic foraminifera. The abundant presence of the planktonic foraminifera along with slightly small benthic foraminifera within the argillaceous limestone layers and marl deposits indicate that deposition took place in a deeper zone of open marine as normal sea salinity below of the Storm Wave Base (SWB) (Wanas, 2008; Wanas et al., 2020). Seddighi et al., (2011) believe that this facies probably deposited in a deeper marine environment. Mohammadi (2020) also believes that these facies deposited in the proximal outer shelf. Slope and toe of slope (Open marine) deposits recognized by the presence of the small size perforate foraminifera as Mf3 and Mf4 (*Amphistgina* and *Miogypsina* associated). The *Miogypsina* and *Amphistegina* are the typical open marine skeletal fauna and indicate that the sedimentation had been took place in the toe of slope/basin below the storm wave base (SWB) (Buxton & Pedley, 1989; Geel, 2000; Beavington - Penney &Racey, 2004; Bassi et al., 2007 and Brandano et al., 2009a).

Also, the abundance of *Amphistegina* (is included more than 50% of the allochems in a thin section) along with the corals and red algae indicates the low to moderate water energy system below the normal wave base (NWB) from fore reef/slope/open marine(Wilson, 1975; Corado and Brandano, 2003; Beavington - Penney & Racey, 2004; Bassi et al., 2007; Barattolo et al.,2007).

In addition, *Amphistegina* lives commonly in the tropical to subtropical environments over a wide bathymetric range, but they are particularly frequent between the interval depths of 40 and 70 m (Hottinger, 1983& 1997). The shoal/reef deposits facies belt (Platform margin) (Read,1995) is dominated by MF5 and Mf 6 as coral boundstone and bryozoans corallinacean packstone. Coral boundstone facies demonstrate the semi-restricted environment and moderate water energy system in the photic zone. According to Flügel (2010), modern tropical and subtropical reefs are located at the margins of shelves and platforms, and on shelves, platforms, and ramps. The red algae and bryozoans association indicate that the sedimentation took place in a platform margin sand shoal environment (High water energy system) (Facies Zone-6 reported by Read, 1995). In addition, Corals, bryozoans and coralline algae association are the main biotic components of the reef environment and they are most significant contributors to Cretaceous, Paleocene, and Eocene platform deposits, and become dominant especially on Oligocene and Miocene carbonate deposits (Aguirre et al., 2000 and Halfar and Mutti, 2005).

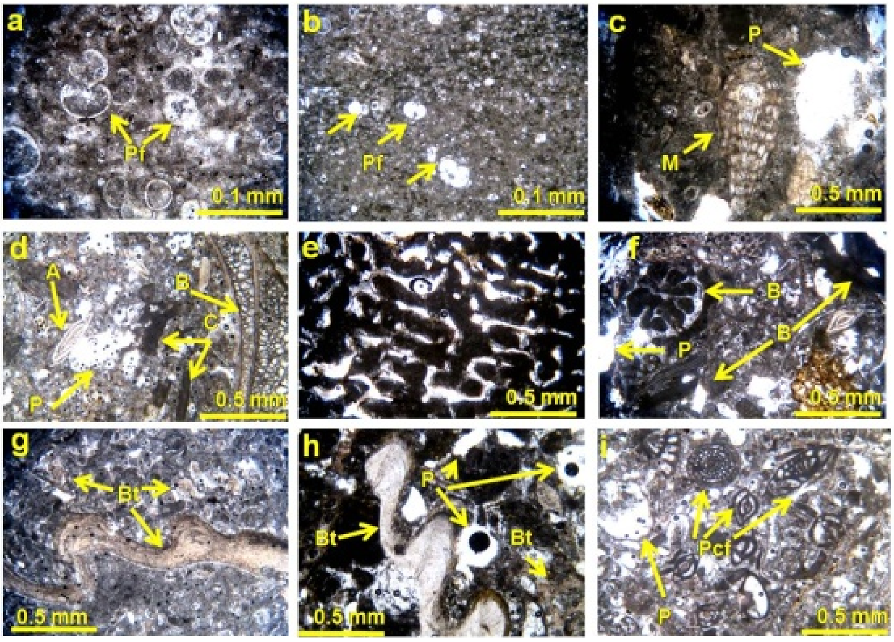

Fig. 5. Photomicrographs of the facies types in the study area (Mf2 to Mf8); a and b: MF2-Planktonic Foraminifera wackestone–packstone(sample numbers:24 & 25); c: Mf 3 -Bioclastic *Miogypsina* packstone (sample number: 31); d: Mf 4– *Amphistegina* Coral corallinacean Packstone (sample number: 7); e: Mf 5 – Coral Boundstone (sample number: 4); f: Mf 6- Bioclastic bryozoan corallinacean packstone (sample number: 3); g and h: MF7- Bioclastic Packstone (sample numbers: 9 & 58); and i: Mf 8- Porcelaneous foraminifera packstone (sample number: 5). Pb:Planktonic foraminifera; M: *Miogypsina*;A: *Amphistegina*;B: Bryozoan; C: Coral; Pct: Porcelaneous foraminifera; Bt: Bioclast; P: Porosity.

Şekil 5. *Çalışma alanındaki fasiyes tiplerinin fotomikrografları (Mf2'den Mf8'e); a ve b: MF2-Planktonik Foraminifera vaketaşı–istiftaşı(örnek numaraları:24 & 25); c: Mf 3-Biyoklastik Miogypsina istiftaşı (örnek numarası: 31); d: Mf 4– Amphistegina Mercan corallinacean istiftaşı (örnek numarası: 7); e: Mf 5 – Mercan bağlamtaşı (örnek numarası: 4); f: Mf 6- Biyoklastik bryozoan korallinacean istiftaşı (numune numarası: 3); g ve h: MF7- Biyoklastik istiftaşı (örnek numaraları: 9 & 58); ve i: Mf 8- Porselen foraminifer istiftaşı (numune numarası: 5). Pb:Planktonik foraminifer; M: Miogypsina;A: Amphistegina;B: Bryozoan; C: Mercan; Pct: Porselen foraminifer; Bt: Biyoklast; P: Porozite.*

The red algae increased in diversity during the Oligocene (Aguirre et al., 2000; Rasser and Piller, 2004) and globally became the dominant Miocene carbonate producers (Halfar and Mutti, 2005; Pomar et al., 2017). According to Hallock (2000) and Hallock et al., (2003), coral reefs thrive in the most nutrient-depleted oceanic waters where mixotrophic nutrition, i.e., the recycling of nutrients between the host and algal symbionts, is most advantageous. Zooxanthellate corals generally thrived in mesophotic conditions during the late Eocene and until the late Miocene (Morsilli et al.,2012).

According to James (1997) and Hallock (2015), ideally, a biogenic reef is a significant, rigid skeletal framework that influences the deposition of sediments in its vicinity and is topographically higher than surrounding sediments.

The lagoonal facies belt (Platform interior environment) (Read,1995) is identified by Mf 7 and Mf8 as bioclastic packstone and presence of porcelaneous foraminifera (thick sequences of calcium carbonates). The bioclast fragments along with some imperforate foraminifera association demonstrate that sedimentation took place in a platform interior environment (Photic zone) (Facies Zone-7 introduced by Read,1995). Shallow water miliolids (alveolinids, peneroplids, and milioloids) are common in lagoons and other quiet environments (Hallock and Glenn, 1986). Abundant smaller miliolids with alveolinids and lacking hyaline taxa indicate shallow waters with some degree of hyper-salinity (Geel, 2000; Hallock et al., 2006). The imperforate foraminifera booming in the upper photic zone and the relative hypersaline environment with limited water circulation (Romero et al., 2002; Mohammadiet al., 2019). The presence of porcelaneous foraminifera (*Borelis*, *Austerotrillina*, and *miliolids*) illustrate warm, euphotic, and shallow water, with low to moderate energy conditions in a semi-restricted and open-lagoon depositional setting (Mohammadi et al., 2011). The high diversity of imperforate foraminifera may be concerning the depositional environment being slightly hypersaline (Geel,2000). The presence of some porcelaneous foraminifera such as Quinqueloculina, *Spiroloculina* and *Peneroplis generally indicate* euphotic *zone, hyper saline water, up to 35 in bathymetry and* temperature 18-35 ° C conditions of *lagoon sedimentary environment (*Flugel,2004; Murray, 1973).The presence *Austrotrillina* suggests epiphytic habitats (Geel, 2000; Bassi and Nebelsick, 2010). Therefore, based on the interpreted depositional environments (lagoon, reef, slope, and open marine) and lacking in the sediment gravity flows, turbidity facies, and abundance in reef facies deposits, an open shelf model suggested probably for the deposition of the Qom Fm. in the Goylar section (Fig. 7). Considerable retrogradation trend in the facies occurred from lagoon/reef facies at the bottom to open marine marls at the top. In addition, sea level fluctuations were dominant and due to the sudden replacement in facies types, active tectonic is proposed for the study area during Early Miocene. It is obvious that active tectonic had been recorded throughout the Central Iran Basin with intensity and weakness, especially for the Oligocene and Miocene basins (Qom Fm.). In the some areas in the Central Iran Basin where the tectonic was active, very often it can be seen that the sedimentary facies of the Qom Fm. experienced rapid changes in terms of depositional setting. Hence, the facies of the Qom Fm. are usually not observed in regular depositional setting in the Central Iran Basin.

CONCLUSION

A 155-m-thick stratigraphic section was selected for the determination of the Qom Fm. depositional setting model in the northwest of the Central Iran (southwest of Zanjan province). Stratigraphic studies showed that the Qom Fm. includes thin to thick-bedded (0.2 to 2.2 m) limestone and alternation of shale, green marl, argillaceous limestone. Micropaleontological studies point out the Qom Fm. is Aquitanian (?) - Burdigalian in age. In the previous studies all kinds of depositional settings including rimmed shelf, open shelf, homoclinic ramp, mixed carbonate–siliciclastic homoclinic ramp, carbonate ramp, carbonate platform, and epicontinental platform, expressed by researchers of the Qom Fm.. In this study, according to facies distribution, a significant retrogradation trend can be seen from lagoon/reef facies toward open marine marls. An open shelf depositional setting is offered for Qom Fm. sedimentation due to the dominant presence of shoal and reef facies along with facies geometry types. The Qom

Fm. sedimentary facies had alternated gradually to drastically during Early Miocene in the study area. Therefore, it can be stated that Qom sedimentation had been controlled by active tectonic. However, this situation can be traced to other parts of the Central Iran Basin.

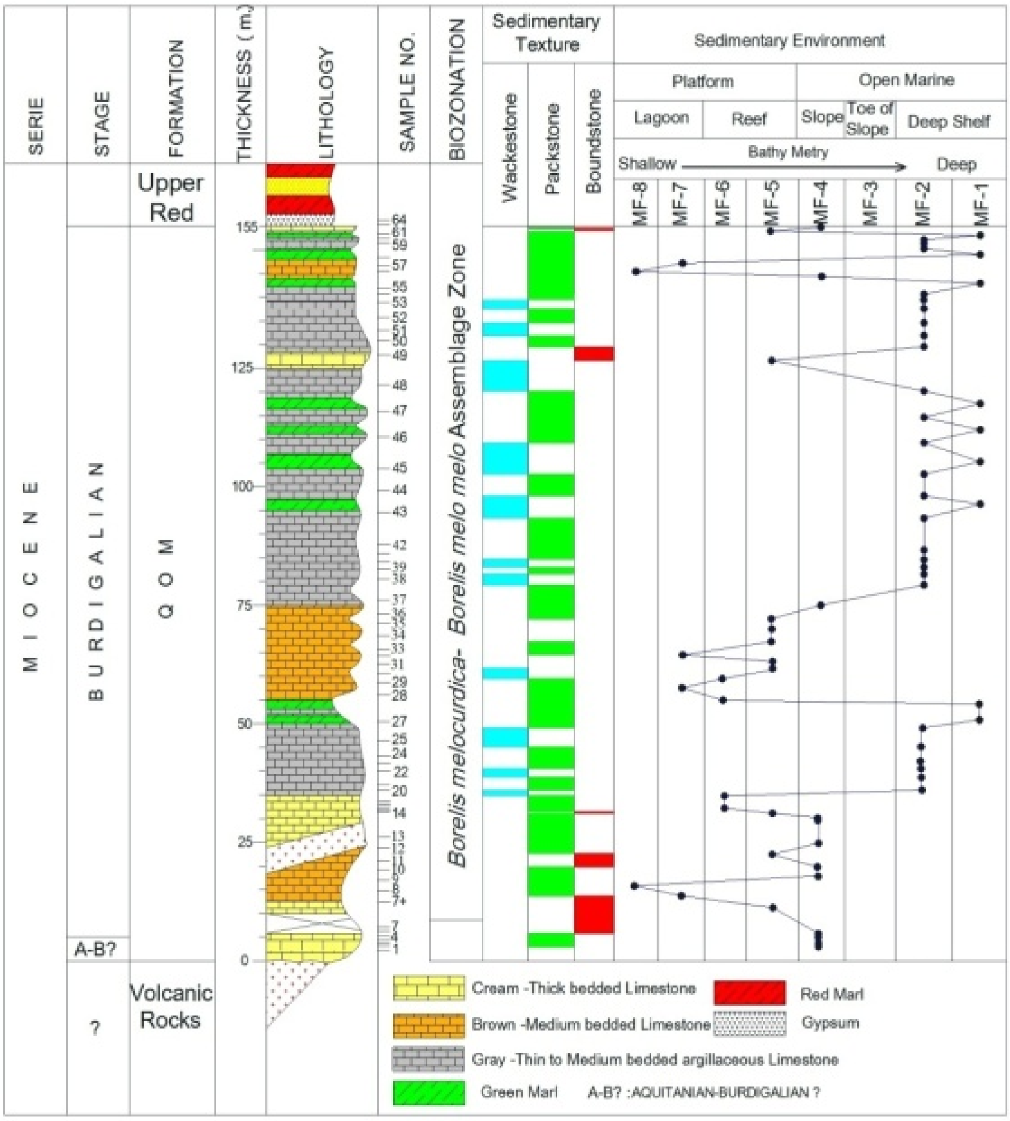

Fig.6. Log of facies distribution from the Goylar stratigraphic section.

Şekil 6. *Goylar stratigrafik kesitinin fasiyes dağılım logu.*

Fig.7. Depositional setting model for the Early Miocene Qom Fm. in the Goylar Section (Based on studies by Read,1995; Wilson, 1975; and Flügel, 2010).

Şekil 7. *Goylar kesitinde Erken Miyosen Qom Fm. için çökelme ortamı modeli. (Read,1995; Wilson, 1975; ve Flügel, 2010 tarafından yapılan çalışmalara dayanmaktadır).*

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