MICROACIES ANALYSIS, DEPOSITIONAL ENVIRONMENT AND POROSITY TYPES OF THE ASMARI FORMATION IN TANG-E-PIRZAL AREA (NORTHEAST OF DEHDASHT), ZAGROS BASIN, IRAN

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ABSTRACT

The Asmari Formation (a giant hydrocarbon reservoir) is a thick carbonate sequence of the Oligocene-Miocene in the Zagros Basin, southwest of Iran. This Formation is exposed at Tang-e-Pirzal in the northeast of Dehdasht with a thickness of 180 meter. Biostratigraphic analysis of this formation has resulted in the recognition of three biozones in the Asmari Formation and the age of this Formation in the study area is the Oligocene (Chattian)-early Miocene (Aquitanian-Burdigalian). In this study, twelve different microfacies types have been recognized, which can be grouped into five depositional environments: tidal flat, restricted lagoon, open lagoon, shoal and slope. This Formation represents sedimentation on a carbonate ramp. In this study, porosity types were divided into primary and secondary porosity groups that affected by sedimentary environment, diagenetic process and tectonic. In high energy microfacies, primary porosity (interparticle and intraparticle types) was formed that interparticle porosity was decreased, but moldic and vugy porosities (secondary porosity) were increased in primary porosity. In studied section, cementation lead to decrease porosity, but dissolution process, dolomitization and tectonic process lead to form vugy, intercrystalin and fracture porosities. The dissolution of unstable minerals is the major process that improves porosity and then permeability by enlarging pores and pore throats.

Keywords: Microfacies, Asmari Formation, porosity, Chattian, Aquitanian, Burdigalian, Zagros Basin.

1) INTRODUCTION

The Asmari Formation is a thick carbonate sequence of the Oligocene-Miocene in the Zagros Basin, southwest of Iran. Lithologically, the Asmari Formation consists of thin, medium to thick and massive carbonate layers. 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. This Formation at the type section consists of 314 m of limestones, dolomitic limestones and argillaceous limestones (Motiei 1993). The Asmari Formation, at its type section, was deposited during the late Oligocene (Rupelian)-early Miocene (Burdigalian). The base of the Asmari Formation varies in age. For instance, toward the coastal Fars area, it is mainly Rupelian while in the Dezful Embayment; it ranges from Rupelian to Chattian (Motiei, 1994). The top of the Asmari Formation, mostly Burdigalian in age, remains constant, but toward the coastal and interior Fars, it is Chattian. The purposes of this paper are: studied 1) Microfacies, 2) Depositional environment and 3) Porosity Types and reservoir quality of the Asmari Formation at Tang-e-Pirzal in the northeast of Dehdasht.

2) GEOLOGICAL SETTING

Based on the sedimentary sequence, magmatism, metamorphism, structural setting and intensity of deformation, the Iranian Plateau has been subdivided into eight continental fragments including Zagros, Sanandaj-Syrjan, Urumieh-Dokhtar, Central Iran, Alborz, Kopeh-Dagh, Lut, and Makran (Heydari et al, 2003; Figure 1). The Zagros basin is composed of a thick sedimentary sequence that covers the Precambrian basement formed during the Pan-African orogeny (Al-Husseini, 2000). The total thickness of the sedimentary column deposited above the Neoproterozoic Hormuz salt before the Neogene Zagros folding can reach over 8 to 10 km (Alavi 2004, Sherkati and Letouzey 2004). The Zagros basin has evolved through a number of different tectonic settings since the end of Precambrian. The basin was part of the stable Gondwana supercontinent in the Paleozoic, a passive margin in the Mesozoic and became a convergent orogeny in the Cenozoic. During the Palaeozoic, Iran, Turkey and the Arabian plate (which now has the Zagros belt situated along its northeastern border) together with Afghanistan and India, made up the long, very wide and stable passive margin of Gondwana, which bordered the Paleo-Tethys Ocean to the north (Berberian and King 1981). By the Late Triassic, the Neo-Tethys Ocean had been opened up between Arabia (which included the present Zagros region as its northeastern margin) and Iran, with two different sedimentary basins on both sides of the ocean (Berberian and King 1981).

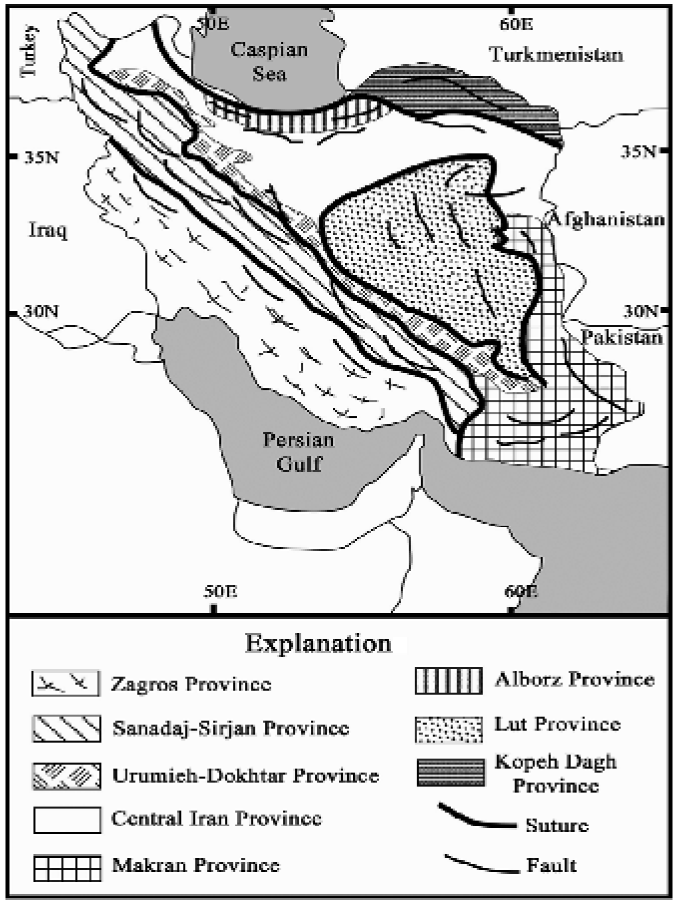


Figure 1. *Subdivisions of the Zagros orogenic belt (adopted from Heydari et al., 2003).*

The closure of the Neo-Tethys basin, mostly during the Late Cretaceous was due to the convergence and northeast subduction of the Arabian plate beneath the Iranian sub-plate (Berberian and King 1981, Stoneley 1981, Beydoun et al. 1992, Berberian 1995). The closure led to the emplacement of pieces of the Neo-Tethyan oceanic lithosphere (i.e., ophiolites) onto the northeastern margin of the Afro-Arabian plate (e.g., Babaie et al. 2001, Babaei et al. 2005, Babaie et al. 2006). Continent-continent collision starting in the Cenozoic has been led to the formation of the Zagros fold-and-thrust belt, continued shortening of the mountain range, and creation of the Zagros foreland basin. The Late Cretaceous to Miocene rocks represents deposits of the foreland basin prior to the Zagros orogeny, and subsequent incorporation into the colliding rock sequences. This sequence unconformably overlies Jurassic to Upper Cretaceous rocks. Compressional folding began during or soon after the deposition of Oligocene-Miocene age Asmari Formation (Sepehr and Cosgrove 2004).

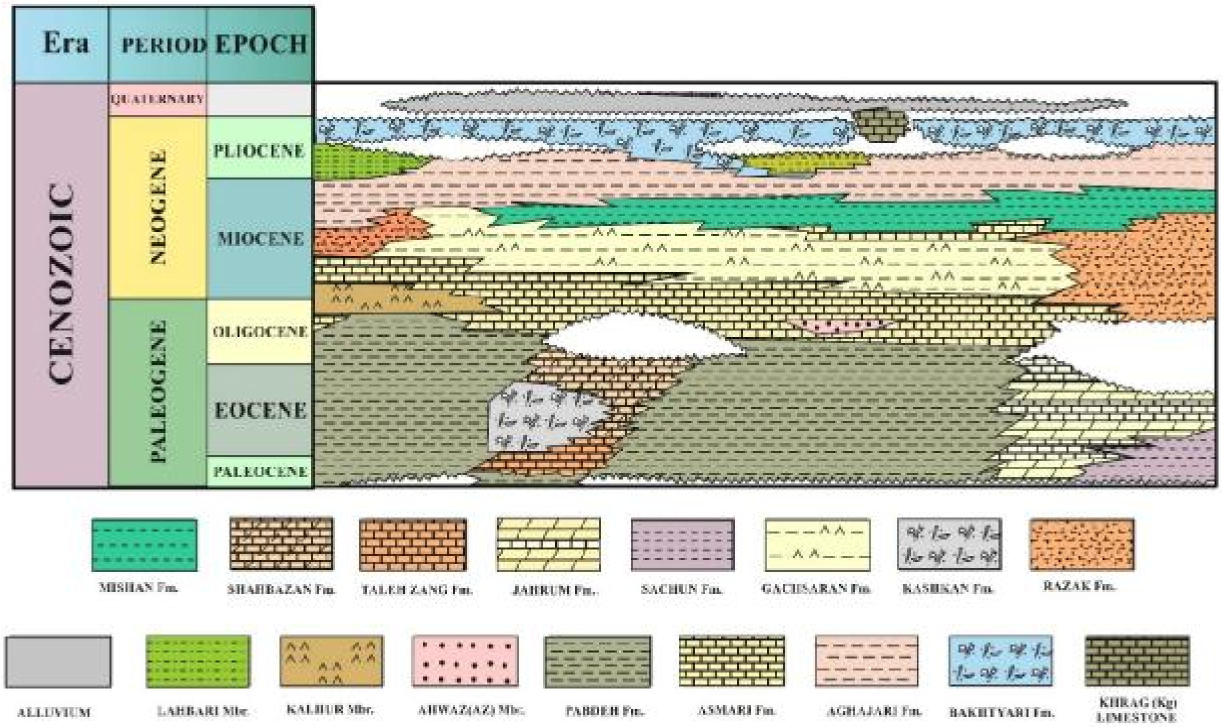


Figure 2. *Schematic section showing the stratigraphic position of the Asmari Formation within the Cenozoic rocks of southwestern Iran (Motiei, 2001).*

During the Palaeocene and Eocene, the Pabdeh (pelagic marls and argillaceous limestones) and the Jahrum (shallow marine carbonates) formations were, respectively, deposited in the middle part and on both sides of the Zagros basin axis (Motiei 1993). During the Oligocene-Miocene age this basin was gradually narrowed and the Asmari Formation was deposited. Different facies, including lithic sandstone (Ahwaz Member) and evaporites (Kalhur Member) were deposited during late Oligocene-early Miocene times (Ahmadhadi et al. 2007). 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 (Figure 2). 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 the Zagros basin. The maximum thickness of the Asmari Formation is found in the northeastern corner of the Dezful Embayment. The study area is located in the Tang-e-Pirzal area in the northeast of Dehdasht, in the fold– thrust zone of the Zagros baisn in southwest of Iran (Figure. 3).

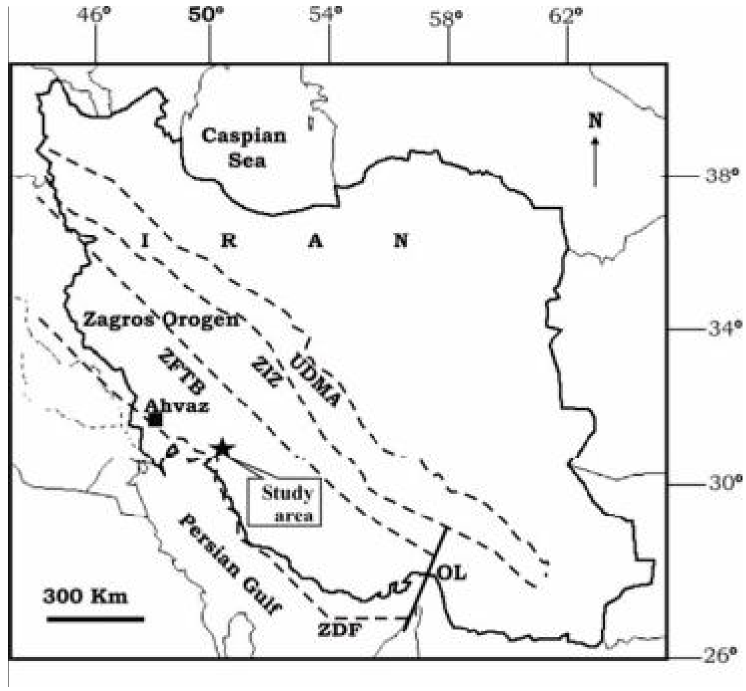


Figure 3. *Subdivisions of the Zagros orogenic belt: OL, Oman line; UDMA, Urumieh-Dokhtarmagmatic arc; ZDF, Zagros deformational front; ZFTB, Zagros fold-thrust belt; ZIZ, Zagros imbricate zone; ZS, Zagros Suture (After Alavi 2004).*

3) PREVIOUS WORKS

The Asmari Formation was originally defined in primary works by Busk and Mayo (1918), Richardson (1924), Van Boeck et al. (1929), Lees and Richardson (1940) and Thomas (1948). Later, James and Wynd (1965), Adams and Bourgeois (1967), Kalantary (1986), Jalali (1987) and Motiei (1993) to review and improve the previous works and define the Asmari Formation throughout the Zagros Basin. Recent works concerning the biostratigraphy of the Asmari Formation are Seyrafian et al. (1996), Seyrafian and Mojikhalifeh (2005), Hakimzadeh and Seyrafian (2008), Amirshahkarami (2008) and Sadeghi et al. (2009), Vaziri-Moghaddam et al. (2010), Maghfouri-Moghaddam (2013, 2015), Roozpeykar (2014,2016), Joudaki and Baghbani (2015), Taheri et al (2017) and Hatefi et al. (2018). Researches concerning the sedimentary and facies analysis and depositional environment of the Asmari Formation are Seyrafian (2000), Seyrafian and Hamedani (2003), Vaziri-Moghaddam et al. (2006), Amirshahkarami et al. (2007a, 2007b), Fakhari et al. (2008), Mossadegh et al. (2009) Allahkarampour Dill et al. (2010, 2012), Sooltanian et al. (2011), Seyrafian et al. (2011), Dehghanian et al. (2012), Hoseinzadeh et al (2015), Lorestani et al. (2016) and Sadeghi et al. (2018). Diagenesis of the Asmari Formation has been recently received more attention (Aqrawi et al., 2006; Ehrenberg et al., 2006; Al-Aasm et al., 2009) and Seyrafian et al. (2010). Also, Researches concerning to Zagros structural style and basin analysis are Sherkati et al. (2006), Ahmadhadi et al. (2008), and Heydari (2008). Depositional and diagenetic processes control the fluid movement and its saturation behavior by forming pores and changing them in the reservoir rocks (Aliakbardoust and Rahimpour-Bonab 2013). Sedimentary and petroleum geologists widely use porosity classification of (Choquette and Pray 1970). This classification is tightly based on sedimentary fabric and so can predicts the types of spaces (porosity) with respect to the depositional provenance or diagenesis evolution. The mentioned classification system is especially useful for study of porosity evolution and exploration of oil and gas. The classification of (Archie 1952) and more recently ones (Lucia 1995, 1999) are used among petrophysist and reservoir engineers due to the direct relationship of this type of classification to pore geometry and fluid properties. Conventional static method in the determination of reservoir rock-types is evaluation of textural properties and porosity types of reservoir rocks and their relationships with petrophysical properties (permeability and saturation) (Granier 2004, Skalinski, M. and Kenter 2013). So study of porosity type and permeability in different parts of hydrocarbon reservoirs is very important for oil and gas production management. So it seems that study of reservoir rock type helps for more hydrocarbons production in oil and gas fields. Many researcher works on reservoir rock types among the rest (Granier 2004, Xu 2012).

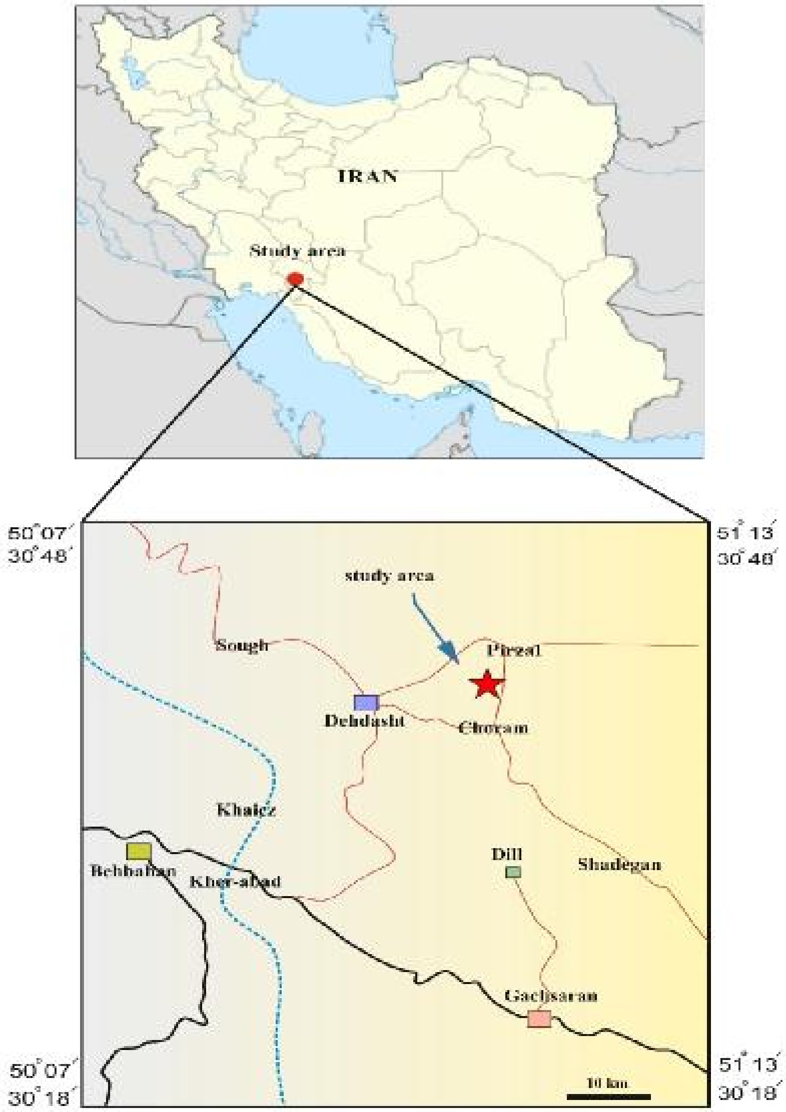


Figure 4. *Locality map of the studied sections.*

4) MATERIAL AND STUDY AREA

The studied section is located at 13 km northeast Dehdasht with geographical coordinates of 30° 46′ 38″ N, 50° 41′ 12″ E (Fig. 4). In this study, the thickness of the Asmari Formation is 180 meter and more than 150 samples from the Asmari Formation were studied. The taxonomic determination of the foraminifers is based on the foraminiferal classifications: Loeblich and Tappan (1988), Rahaghi (1983) and Hottinger (1983 and 1999). Petrography and microfacies types were described based on Dunham (1962). Facies definition was based on the microfacies characteristics, including depositional texture, grain size, grain composition, and fossil content (Flugel 2004). Biozoations established for the Asmari Formation in this study are largely based on biozonation of Laursen *et al*. (2009) that comprises an Oligocene Miocene Carbonate sequence. Porosity types classification of the Choquette and Pray (1970) in Table 1.

Table 1. *Philip Choquette and Lloyd Pray's carbonate porosity classification (Choquette and Pray 1970).*

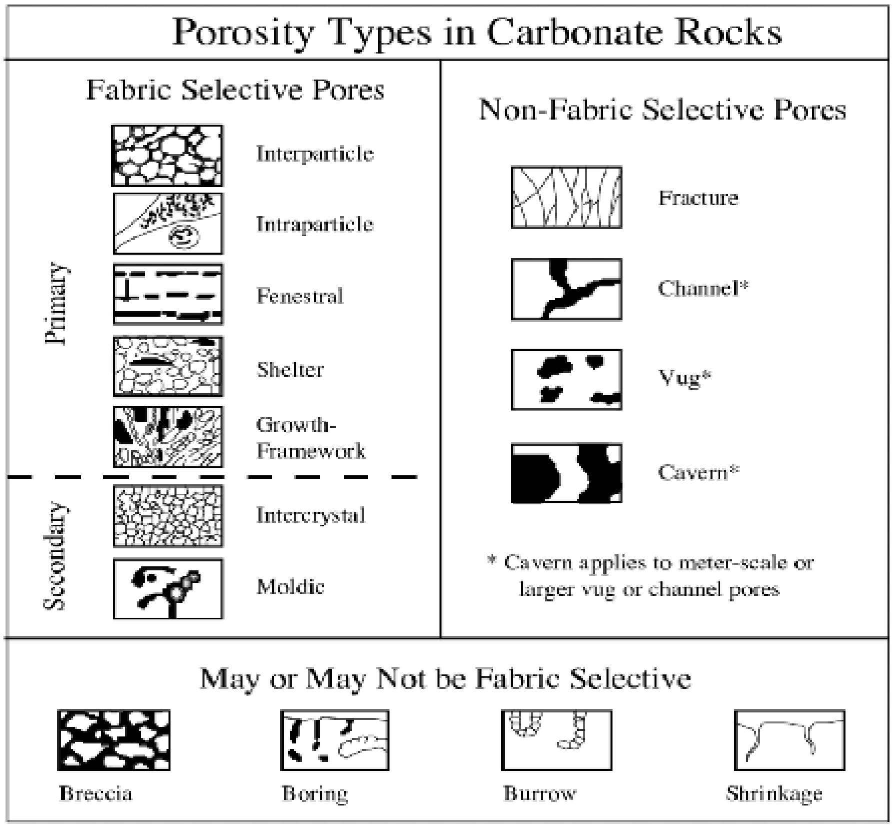
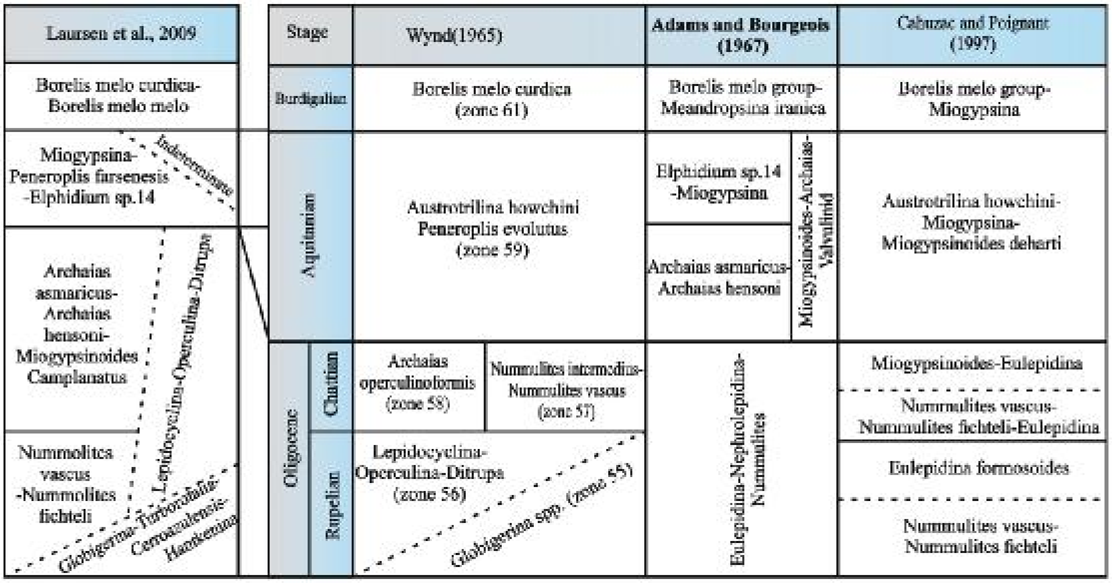


Table 2. *Comparison of biostratigraphic zonation for the Asmari Formation (modified after Van Buchem et al. 2010)*



5) BIOSTRATIGRAPHY

Biozonation and age determinations are based on strontium isotope stratigraphy recently established for the Asmari Formation by Laursen *et al.* (2009). Results from the foraminifer's data are summarized in Table 2.

Three assemblages of foraminifera were recognized in the studied areas and were discussed in ascending stratigraphic order as follows:

Assemblage 1. This assemblage consists of: *Operculina* sp., *Operculina complanata, Lepidocyclina* sp., *Ditrupa* sp., *Heterostegina* sp., *Eulepidina elephantine, Eulepidina dilatata, Nephrolepidina tournoueri, Rotalia* sp., *Rotalia viennoti, Amphistegina* sp., *Onychocella* sp., *Valvulinid* sp., *Pyrgo* sp., *Tubucellaria* sp.

This biozone is located in the lower part of the Asmari Formation in the studied area and this assemblage is correlated with *Lepidocyclina-Operculina-Ditrupa* assemblage zone of Laursen *et al*. (2009). The assemblage is considered to be Chattian in age.

Assemblage 2. This assemblage consists of: *Archaias kirkukensis, Archaias* sp., *Elphidium* sp., *Miogypsina* sp., *Miogypsinoides* sp., *Asterigerina* sp., *Dendritina* sp., *Rotalia viennoti, Peneroplis farsensis, Peneroplis* sp., *Peneroplis evolutus, Valvulinid* sp., *Discorbis* sp., *Austrotrillina howchini, Austrotrillina* sp., *Spirolina* sp., *Rotalia* sp., miliolids, *Heterostegina costata*, *Lepidocyclina* sp., *Nephrolepidina* sp., *Amphistegina* sp., *Eulepidinan* sp., *Archaias hensoni., Meandropsina* sp., *Archaias operculiniformis, Ditrupa* sp., *Borelis* sp., *Spirolina cylindracea, Borelis pygmaea, Meandropsina anahensis.*

This biozone is located in the middle part of the Asmari Formation in the studied area and this assemblage corresponds to the *Miogypsina-Elphidium* sp. 14-*Peneroplis farsensis* assemblage zone of Laursen *et al*. (2009). The assemblage is considered to be Aquitanian in age.

Assemblage 3. This assemblage consists of: *Borelis* sp., *Borelis melo curdica*, *Dendritina rengi*, *Miogypsina* cf. *irregularis*, *Elphidium* sp., *Discorbis* sp., *Meandropsina* iranica, *Peneroplis thomasi*, *Peneroplis evolutus*, *Bigenerina* sp., *Rotalia* sp., *Schlumbergerina* sp., *Valvulinid* sp., *Miogypsinoides* sp., *Triloculina trigonula*, *Pseudotaberina malabarica, Triloculinatri tricarinata*., *Austrotrillina howchini*, *Austrotrillina asmariensis, Archaias kirkukensis, Archaias asmaricus*.

This biozone is located in the upper part of the Asmari Formation in the studied area and this assemblage is correlated with *Borelis melo curdica-Borelis melo melo* assemblage zone of Laursen *et al*. (2009). The assemblage is considered to be Burdigalian in age.

6) MICROFACIES ANALYSIS

Facies analysis of the Asmari Formation in the study areas resulted in the definition of ten facies types (Fig. 5 and 6), which characterize platform development. Each of the microfacies exhibits typical skeletal and non-skeletal components and textures. The general environmental interpretations of the microfacies are discussed in the following paragraphs.

MF1: Fenestrate mudstone

This facies consists of fine grained microcrystalline limestone. Bioclasts are lacking and the fenestrate structures are well developed. This facies mostly occurs with quartz mudstone.

Interpretation: Fenestrate structures are typical products of shrinkage and expansion, gas bubbles, and air escape during flooding, or may even result from burrowing activity of worms or insects. Shinn (1983) considered similar facies representative of a tidal flat environment, where trapped air between irregularly shaped deposits leads to the development of Birdseyes.

MF2: Quartz mudstone

This facies is composed of dense lime mudstones. Sediments also contain sparse unidentified fauna. In some samples, subordinate amounts of detrital quartz grains and gypsum are also present. This facies occurs in middle and upper parts of the Asmari Formation.

Interpretation: Lime mudstone, quartz grains and no evidence of subaerial exposure, was deposited in near-shore, very shallow, low-energy restricted settings seaward of tidal flat. This facies refer to hypersaline situations within a shelf lagoon (Amirshahkarami et al. 2007a, 2010; Taheri et al. 2008, 2010; Rahmani et al. 2009, Vaziri-Moghaddam et al., 2010, Saleh and Seyrafian 2013, Sooltanian et al. 2011, Sahraeyan et al. 2014).

MF3: Bioclastic mudstone with gypsum

This microfacies is composed of bivalve, echinoid, gasteropodas fragments and dense lime mudstones. Sediments also contain sparse unidentified fauna. In some samples, subordinate amounts of detrital quartz grains and gypsum are also present. This facies occurs in upper parts of the Asmari Formation.

Interpretation: Lime mudstone, bivalve, echinoid, gasteropodas fragments with gypsum blades and small quartz grains and no evidence of subaerial exposure, was deposited in a restricted shelf lagoon. This facies indicates hypersaline conditions within a shelf lagoon.

MF4: Bioclastic wackestone packstone

This facies is characterized by the dominant presence of bivalve, echinoid, corallinacean, gasteropodas fragments and other components such as smaller benthic foraminifera (miliolids, *Dendritina* and *Rotalia*), and rare peloids. Textures are dominantly wackestone.

Interpretation: This facies was deposited in a very shallow marine environment of restricted lagoon environments. Evidence for this interpretation includes bivalve, echinoid, corallinacean and gasteropodas fragments and the paucity of fauna (small *Rotalia*, *Dendritina* and miliolids) both in diversity and abundance, and stratigraphic position (Rasser et al. 2005).

MF5: Peloidal miliolid grainstone

This microfacies contains common peloids, miliolid, *Peneroplis*, *Meandropsina*, *Dendritina* and bivalves, echinoderms, gastropoda fragments. The grains are moderately sorted to well sorted, fine to medium sand size, and vary from subangular to round.

Interpretation: The fragmented fauna, well-sorted components, and grainy texture suggests a high-energy shoal environment above the fair-weather wave base, separating the open marine from a more restricted lagoon environment (Flugel 2010, Khatibi-Mehr and Adabi 2013).

MF6: Miliolid, ooid Packstone-Grainstone

This facies is composed of imperforate foraminifera (miliolids) and ooids. Other common constituents include mollusca, corallinacean, coprolite, ooid and benthic foraminiferas such as *Peneroplis, dendritina discorbis*.

Interpretation: This facies was deposited in restricted circulation condition in a protected lagoon environment. The abundance of ooids, miliolids and the moderate diversity of fauna support this interpretation. The oligotypic fauna (such as miliolids) and the presence of a low-variety foraminiferal association signify a very shallow subtidal environment with low to moderate energy (Rahmani et al., 2010, Sooltanian et al. 2011, Sahraeyan et al. 2014) and low water turbulence (Geel 2000) as well as high salinity.

MF7: Bentic foraminifera *(Archaias, Peneroplis, Meandropsina, Borelis, Austrotrillina, Dendritina* and miliolids) packstone-grainstone

This facies is characterized by the dominant presence of benthic imperforate foraminifera (*Archaias, Peneroplis, Meandropsina**,** Borelis, Austrotrillina, Dendritina* and miliolids) and other components such as bivalves and gastropods (whole shell and broken fragments). The grains are poorly to medium sorted, are fine-to medium size and vary from sub-angular to semi-rounded. Textures are dominantly packstone to grainstone.

Interpretation: This facies was deposited in a restricted shelf lagoon. The restricted condition is suggested by the rare to absent normal marine biota and abundant skeletal components of restricted biota (imperforate foraminifera such as *Archaias, Peneroplis, Austrotrillina, Dendritina* and miliolids). The subtidal origin is supported by the lack of subaerial exposure and stratigraphic position. This microfacies represents the shallowest upper part of the photic zone, with very light, highly translucent.

MF8: Bentic foraminifera (perforate and imperforate) packstone-wackestone

The main characteristic of this facies is benthic foraminifera in mud-supported textures. Benthic foraminifera include *Archaias, Peneroplis, Meandropsina**,** Borelis, Austrotrillina, Dendritina, Alveolinia, Operculina, Elphidium, Valvulinid, Heterostegina, Lepidocyclina, Amphistegina*, miliolids, and *Rotalia* sp., other components such as corallinacean, echinoids and peloids, are subordinate. Rare to common bivalves are also present. Texture varies from packstone to wackestone.

Interpretation: The co-occurrence of normal marine biota such as *Rotalia*, corallinaceans and echinoids with lagoonal biota such as miliolids, indicates that sedimentation took place in an open shelf lagoon. A similar facies with imperforate foraminifers and perforate foraminifers was reported from the inner ramp of the Oligosen-Miocene sediments of the Zagros Basin (Vaziri-Moghaddam *et al*. 2006).

MF9: Bioclastic ooids grainstone

The predominant grain types are skeletal fragments and ooids. Biotic grain types include echinid and gastropods. Ooid nuclei consist of recrystallized bivalve fragments, *Peneroplis, Austrotrillina, Dendritina* and miliolids, with oval, circular or elongate outlines. Grains are fine- to coarse-sand size and sorting is moderate.

Interpretation: The features of this facies indicate moderate to high energy shallow waters with much movement and reworking of bioclasts and the production of ooids. Sediments are interpreted to have been deposited in sand shoal (Wilson 1975, Flügel 2004).

MF10: Bioclastic coral floatstone

This microfacies is predominantly composed of coral colonies and echinoid fragments. Additional components are bryozoan, corallinacean, mollusca, and small benthic foraminifers (*Rotalia*, *Heterostegina*, *Valvulinid*, *Amphistegina*). Grains are poorly sorted. In some samples *Rotalia* and coral are abundant

Interpretation: The presence of varied and stenohalynfauna including corallinacean, coral and benthic foraminifera refer to upper part of acarbonate slope environment in oligotrophic situation (Wilson 1975, Riding et al. 1991, Longman 1981, Flügel 1982, Melim and Scholl 1995, Pedley 1996, Pomar 2001a, Taheri 2010)

MF11: Nummulitidae lepidocyclinidae bioclast grainstone

The main components are small perforate foraminifera and abundant fragments of corallinacean, bryozoans and bivalve. The foraminifera are characterized by a relatively diverse assemblage of *Lepidocyclina, Heterostegina* and *Rotalia*. Textures is dominantly grainstone.

Interpretation: The existence of abundant fragments of corallinacean, small benthic foraminifera with perforate walls (*Lepidocyclina*, *Heterostegina* and *Rotalia*) in this microfacies indicates deposition in shallow marine conditions within the euphotic zone and the grainstone texture suggests sufficient energy to winnow away the fines in this microfacies.

MF12: Bioclastic nummulitidae lepidocyclinidae grainstone-packstone

Th is microfacies type is a grain-supported texture (grainstone-packstone) with densely packed, flat larger benthic foraminifera. The foraminiferal assemblage comprises numerous perforated larger foraminifera such as Lepidocyclinidae and Nummulitidae. The Nummulitidae are represented by *Operculina, Heterostegina* and. Other skeletal grains include bryozoans, corallinaceas, gastropoda, echinids, ostracods and small benthic foraminifera.

Interpretation: This microfacies was deposited in a medium-high energy open marine environment. This interpretation is supported by the abundance of typical open marine skeletal fauna including large and flat Nummulitidae, Lepidocyclinidae, bryozoans, and echinoids (Romero *et al.* 2002). The presence of those fauna, in comparison with analogues in modern platforms (Hottinger 1983, Reiss & Hottinger 1984, Leutenegger 1984, Hohenegger 1996, Hottinger 1997, Hohenegger *et al*. 1999), suggests that this microfacies type has been deposited in the lower photic zone. This microfacies has also been reported from the lower parts of the Asmari Formation in other sections, such as Chaman-Bolbol and Tang-e-Gurgdan (Amirshahkarami *et al*. 2007a, 2007b).

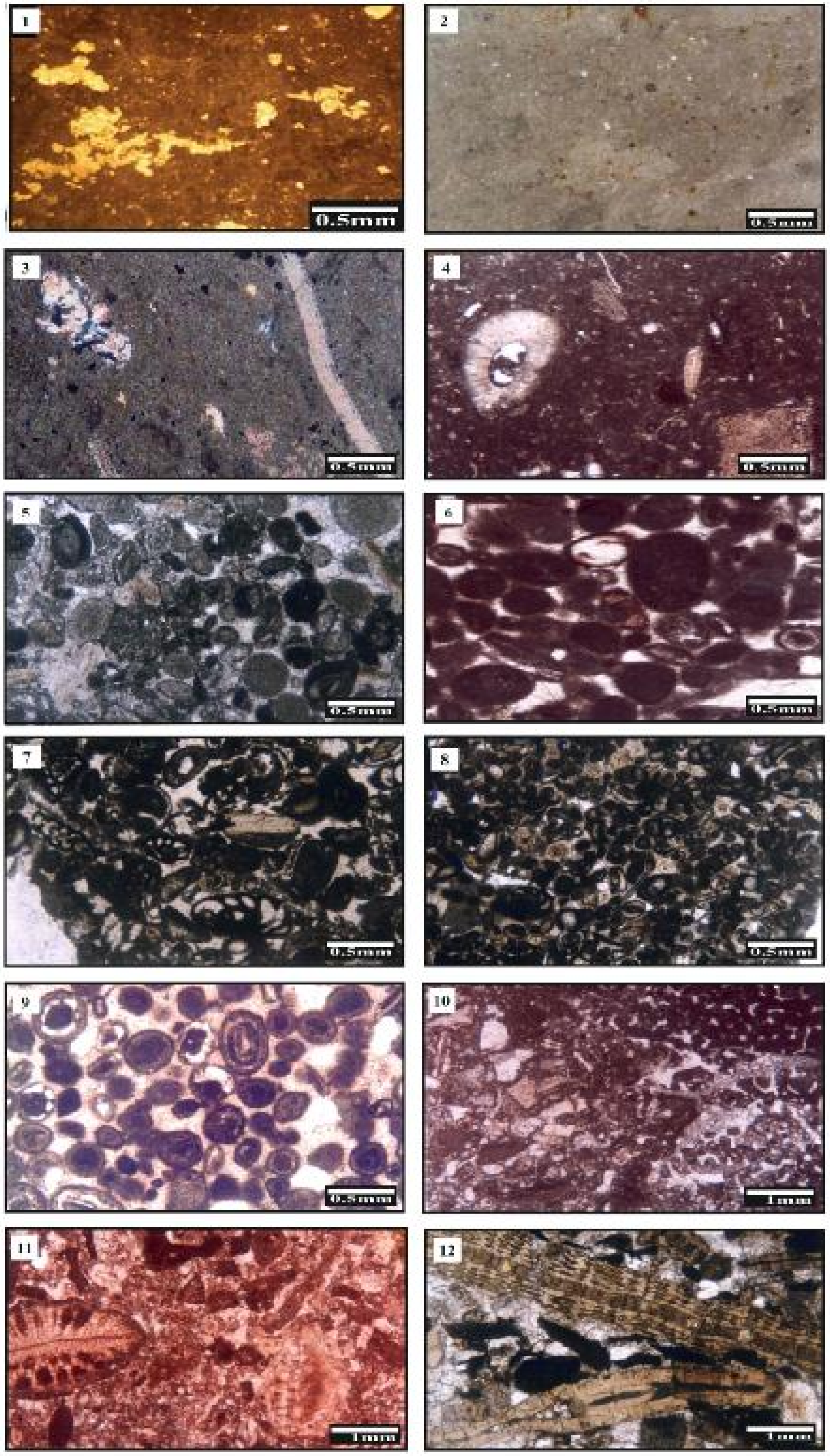


Figure 5. *Microfacies of the Asmari Formation. 1) Quartzarenite, 2) Quartz mudstone, 3) Bioclastic mudstone with gypsum, 4) Bioclastic wackestone packstone, 5) Peloidal miliolid grainstone, 6) Peloid packstone-grainstone, 7) Bentic foraminifera (Archaias, Peneroplis,*

Meandropsina, Borelis, Austrotrillina, Dendritina and miliolids) packstone-grainstone, 8) Bentic foraminifera (perforate and imperforate) packstone-wackestone, 9) Bioclastic ooids grainstone, 10) Bioclastic coral floatstone, 11) Nummulitidae lepidocyclinidae bioclast packstone-grainstone, 12) Bioclastic nummulitidae lepidocyclinidae grainstone-packstone.

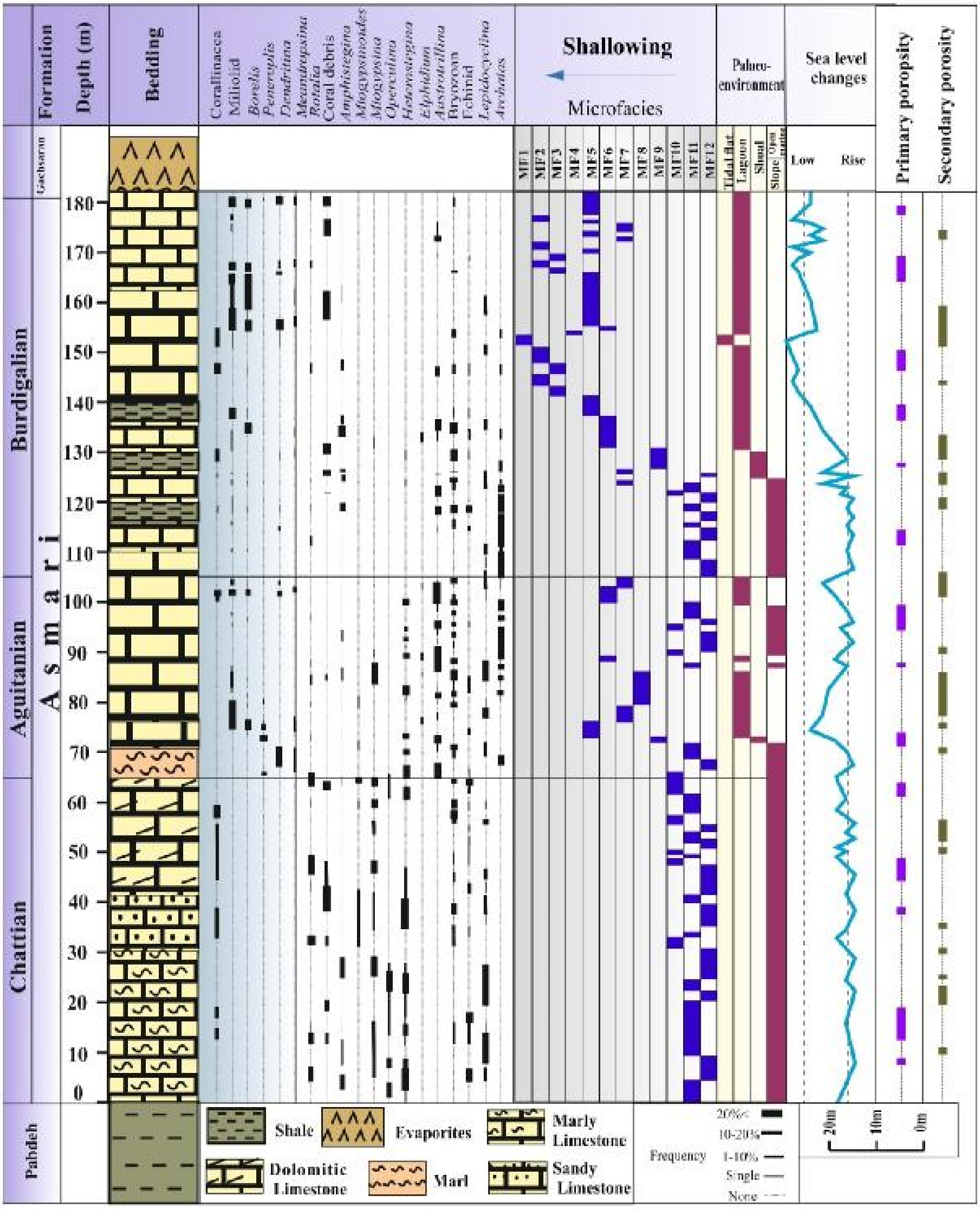


Figure 5. Lithology, biostratigraphy, microfacies, paleoenvironment and estimated porosity percentages for the Asmari Formation at the study area.

6) SEDIMENTARY MODEL

The Asmari Formation was deposited on a carbonate shelf (Read 1982; Tucker 1985; Tucker and Wright 1990) dominated by large bentic foraminifera, coralline algae and subordinately, echinoids, bryozoans, colonial corals. Basis of stratigraphy, sedimentology, distribution of foraminifera and vertical facies relationships, three depositional environments are identified in the Oligocene-Miocene succession in the studied section. These include inner shelf/ lagoon, shoal and middle shelf (Burchette and Wright 1992) (Fig. 7). The paleolatitudinal reconstructions (Alavi 2007) and skeletal grains suggest that carbonate sedimentation of Asmari Formation took place in tropical waters under oligotrophic to slightly mesotrophic conditions. The inner shelf ramp biotic accumulation represents a wider spectrum of marginal marine deposits indicating of tidal flat, restricted lagoon and open lagoon. The tidal flat setting is identified by fenestral lime mudstone and quartz mudstone (MF1). The faunal variety of the protected lagoon setting (MF 2, 3, 4, 5, 6 and 7) is low and normal marine fauna are lacking. The epiphytic foraminiferal fauna (*Archaias*, *Peneroplis*, *Borelis*) (Brandano et al., 2009) were the best accommodated fauna to the paleoenvironmental conditions such as low turbidity, highlight intensity, low-substrate stability and points to meso-to- oligotrophic settings at shallow depths (Hallock 1984, 1988; Reiss and Hottinger 1984, Buxtonand Pedley 1989, Romero et al., 2002, Barattolo et al., 2007). Today, porcelaneous larger foraminifera prosper in tropical carbonate platforms within the upper partof the photic zone. In addition, miliolids are indications of very shallow, hyposaline to hypersaline and restricted environments (Murray 1991) and reflect decreased circulation and likely reduced oxygen contents or euryhaline conditions. Open lagoon shallow subtidal environments are characterized by imperforate foraminifera with the plentifulness of perforate foraminifera such as *Amphistegina* and *Rotalia* (MF 8). The sorting and grainy texture suggests a high energy environment for MF 9. The sediments would have been deposited in a shoal environment which separating the open marine from more restricted marine environment (Flugel 2004). The whole tests of perforate foraminifera are the dominant microfauna of the intermediate to distal middle ramp (MF10). The proximal middle ramp dominated by corallinacean and small perforates foraminifera (MF11). The middle shelf association consists of large perforate foraminifera (nummulitids, lepidocyclinids, *Amphistegina*, *Operculina*) and fragments of echinoid and corallinacean (MF12). Mainly, the lower part of the upper photic zone is controlled by perforate hyaline foraminifera that points to low hydrodynamic energy, lower limit of the photic zone, oligothrophy and normal salinity (Leutenegger 1984, Romero et al. 2002). In this study area, are not evidences of the outer shelf environment because this setting is characterized by fine-grained, well-bedded and laterally continuous deposits marked by abundance planktonic foraminiferal content.

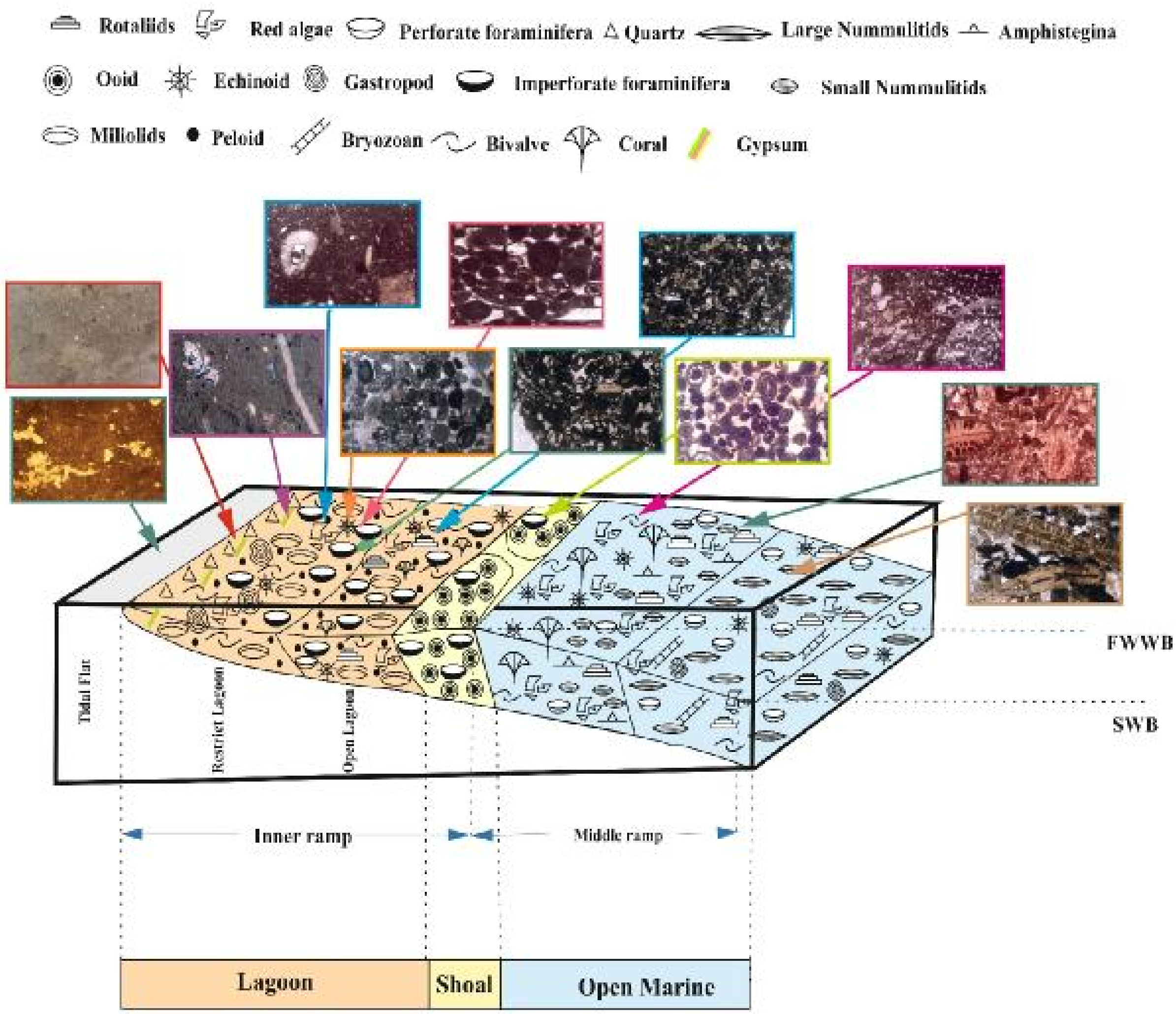


Figure 7. *Depositional model of the Asmari Formation at the study areas.*

7) POROSITY TYPES IN THE ASMARI CARBONATE RESERVOIR ROCK

Types of porosity and pore throat between them plays important role in hydrocarbons, storage and production (Anovitz and Cole 2015, Dernaika et al 2015). In this study, the porosity types (primary and secondary) (Fig. 6) detected in the Asmari Formation reservoir in the study area are as follows (Motiei 2003, Fig. 8):

7.1) Primary Porosity in the Asmari Formation

The types of primary porosity detected in the Asmari reservoir in the study area include:

7.1.1) Interparticle Porosities

The types of porosity divided into intercrystalline and Intergranular porosity. This porosity group is very useful for permeability of reservoir (Lucia 1995, 2007).

7.1.1.1) Intercrystalline Porosity (Fig. 9. A)

This type of porosity is formed in the existing space among the dolomite crystals and their geological origin is from tidal flat to open marine. This porosity is one of the best spaces for gas reserves in the gas field.

4.1.1.2) Intergranular Porosity (Fig. 9. B)

This type of porosity usually is developed in the spaces among ooid allochems and skeletal grains in the study sequences.

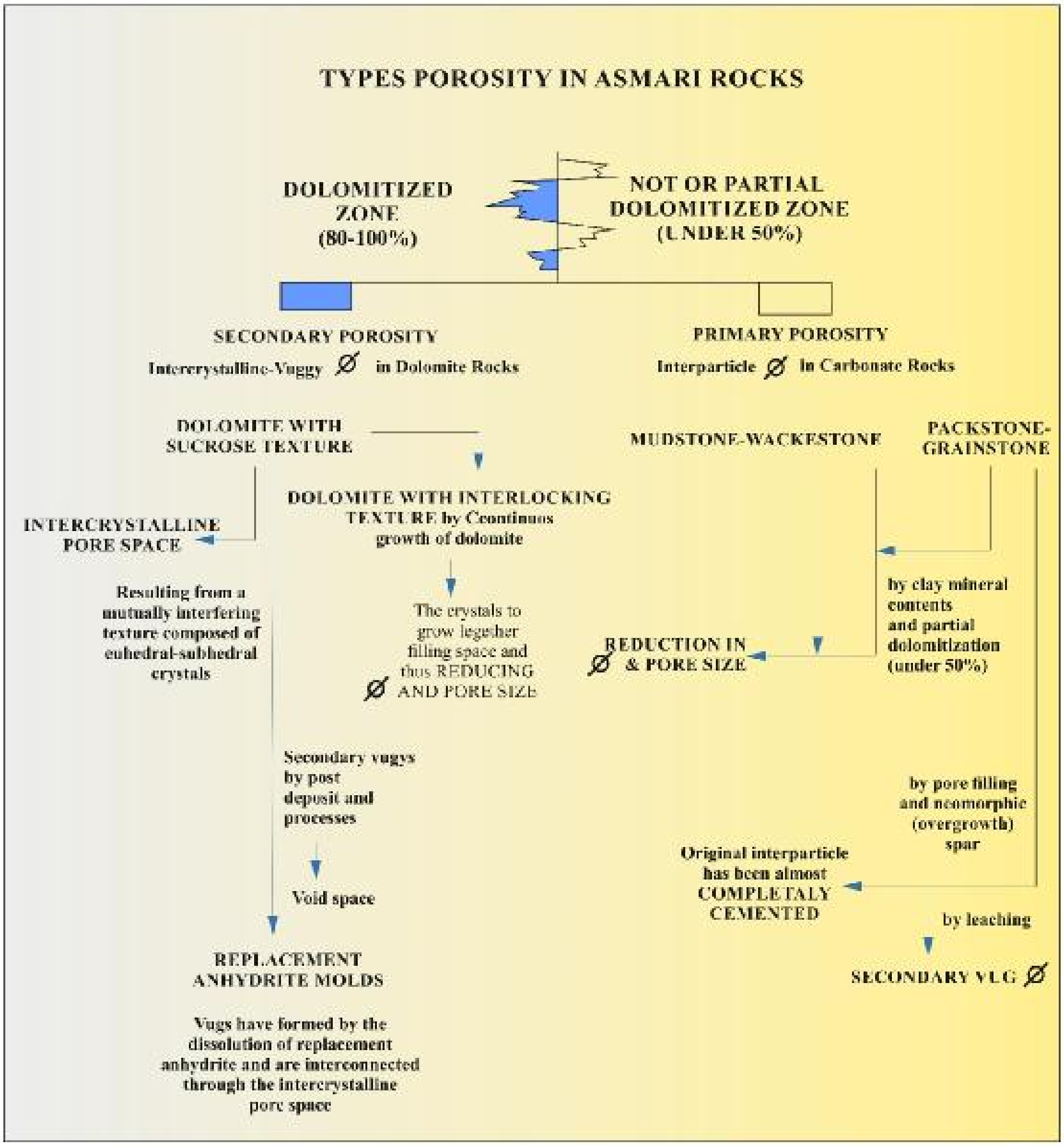


Figure 8: *Types porosity in the Asmari Formation. (Motiei 2003)*

7.1.2) Intrarparticle (Fig. 9. C)

This type of porosity usually is the present in carbonate grains, and the primary cavities are seen in the skeletal body after their death. For example, we can mention the holes in the foraminifera, bryozoa, coral, etc. (Mussavi Harami, 2004).

7.1.3) Framework growth (Fig. 9. D)

The porosity of the framework is due to the growth of living organisms in the aquatic environment and the creation of a space between these frameworks (coral reefs). Microcrystalline cement is observed in the reefal setting that covered by the coarse scalenohedral crystals. Also, isopachous radial fibrous cement is distinguished in some reef pores shows undulose distinct. Primary framework growth porosity between coral skeletal has decreased due to early isopachuos cementation and filling with internal sediments. Syntaxial cement over the echinoid.s fragments can significantly reduce the interparticle porosity (Wardlow, 1976) and occluded throat pores. Other processes that will reduce porosity in the reef cavities are internal sedimentation (regardless of its origin).

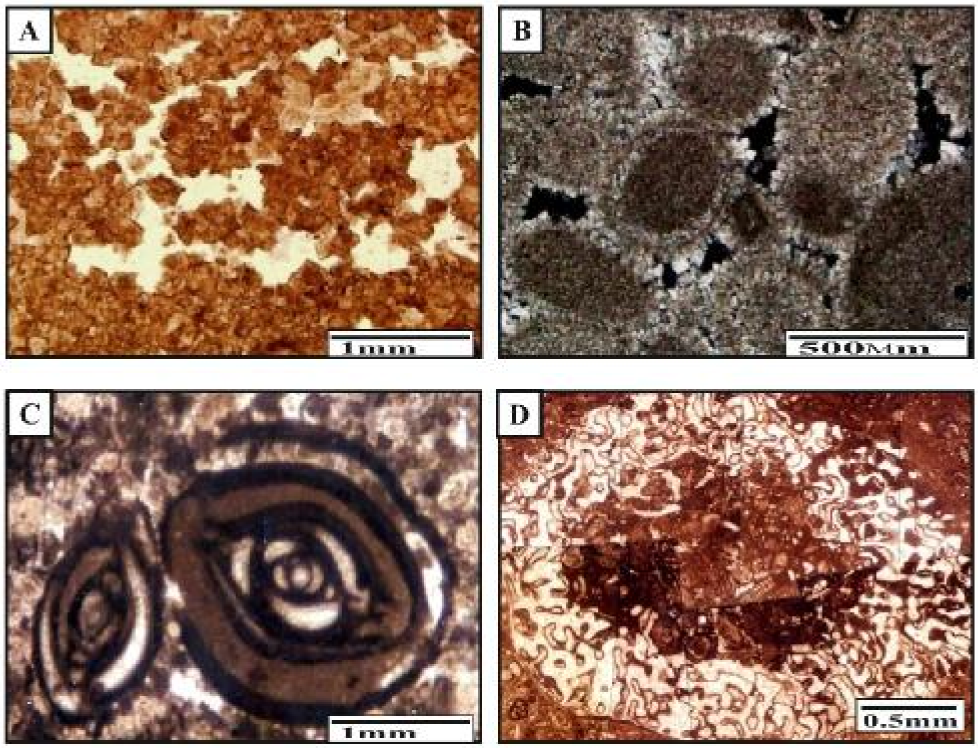


Figure 9. *Types of primary porosity. (A) Intercrystalline porosity. This porosity occurs in spaces among dolomite crystals in a dolostone. (B) Intergranular porosity formed in spaces among ooids, (C) Intrarparticle porosity. This porosity is the present in miliolids, (D) Framework growth porosity. This porosity is the present in space between coral.*

7.2) Secondary Porosity in the Asmari Formation

The types of secondary porosity detected in the Asmari reservoir in the study area include:

7.2.1) Vuggy porosity

Vuggy porosity is divided into Touching-Vuggy and Separate-Vuggy porosity.

7.2.2) Touching-Vug Porosities (Fig. 10. A)

These groups include fracture, shear, vuggy and fenestral porosities. The group is usually non-fabric selective. Porosities of the group are usually are connected together to form a network and could be helpful for permeability of gas reservoirs (Lucia 1995, 2007). In the study area, brecciated porosity is more important.

1) Brecciated porosity

Brecciating of carbonate rocks may occur in the following conditions: collapse of evaporate and carbonate rocks in respect to the dissolution and other similar phenomena. This type of porosity is not very abundant in the study area but it makes the reservoir rock with high quality.

7.2.3) Separate-Vug Porosities (Fig. 10. B)

Generally, these kinds of porosities include moldic and shelter types. In this group, porosity is usually seen as separate vugs or slightly connected pores (indirectly). These types of porosities are fabric selective and usually increase the reservoir porosity not the reservoir permeability (Lucia 1995, 2007). In the studied rocks, the moldic porosity is more important than the other types.

1) Moldic porosity

Moldic porosity is the most abundant porosity in the study area. It usually seen in ooids and skeletal facies. The porosity usually occurs as a selective dissolution process by dissolving of fossils and allochems. The porosity may occur during the early diagentic stage but it is generally the result of the secondary diagenesis in meteoric environment with water under-saturation of carbonate ions accompanied with the high water flow (Simo et al. 1994).

7.2.4) Fructure porosity (Fig. 10. C)

This type of porosity produced by the tectonic fracturing of rock, especially in tectonical areas, also slipping, falling and compression may result in the small fractures inside sediments during sedimentation and create cavities. This type of porosity in addition to sandstones and carbonates may also be seen in shale, igneous rocks and metamorphism (Mussavi Harami, 2004).

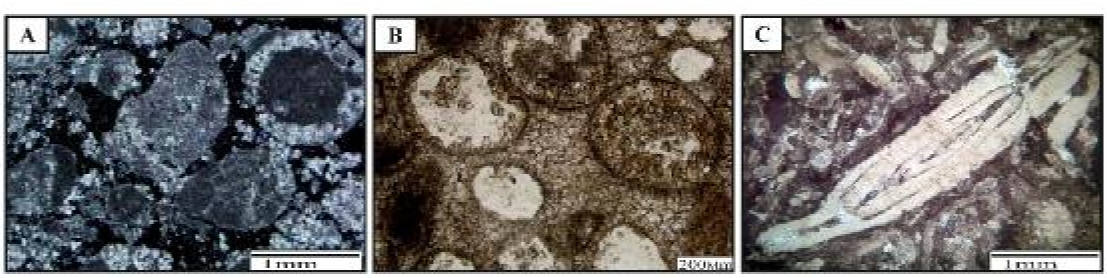


__Figure 10.__ Types of scondary porosity. (A) Brecciated porosity in a skeletal-ooid grainstone. (B) moldic porosity occurs by dissolution of ooids. (C) Fructure porosity occurs by the tectonic fracturing in the operculina.

Dissolution degree of carbonates depends on the mineralogy of the sediments or rocks (Longman 1980, Moore 1989). At the beginning of this phase, dissolution of aragonite particles created moldic porosity. With increased saturated water by calcium carbonate, carbonate cement fills the porosity. Dissolutions that observed in these sections more depends on rock Fabric (moldic porosity). There are a few vuggy pores that do not depend on the Fabric. Secondary porosity in the Asmari Formation result of dissolution after the sedimentation and including developed inter and intraparticle porosities that all shows selective texture. For example, Bioclastic ooid grainstones in the middle and upper part of Asmari Formation have been deposited in a high energy environment and have high interparticle porosity and permeability. In the facies that are formed in the Lagoon environment, only grains were dissolved, so samples have porosity and no permeability. But fractures in the reservoir rock have connected porosities and increased permeability. Figure 6 shows sedimentary porosity distribution (secondary porosity) through the Asmari Formation in the study area.

8) CONCLUSIONS

8.1) In this research based on the micropaleontological analysis of the larger benthic foraminifera and their distribution, three assemblage zones have been recorded. Three assemblages (1, 2 and 3) are present in the studied section (in Tang-e-Pirzal area, northeast of Dehdasht). Assemblages 1 indicate the Chattian age, assemblage 2 is restricted to the Aquitanian age, and assemblages 3 suggest the Burdigalian age. According to this study, the age of the Asmari Formation ranges from the Oligocene (Chattian) to Early Miocene (Aquitanian-Burdigalian).

8.2) Twelve facies were identified on the basis of the sedimentary features of the study sediments and the identified faunal assemblages. Based on the facies groups and the faunal constituents, the carbonate sediments of the Asmari Formation were deposited in a carbonate ramp in the photic zone of a marine zone.

8.3) The outcrops of the Asmari Formation in the study area allow the recognition of different depositional environments, on the basis of microfacies analysis, distribution of foraminifera. These depositional environments correspond to inner and middle ramp. In the inner ramp, the most abundant lithofacies are medium-grained wackestone–packstone with imperforated foraminifera. The middle ramp is represented by packstone–grainstone to floatstone with a diverse assemblage of larger foraminifera with perforate wall (nummulitidae and lepidocyclinidae), red algae, coral, bryozoa, and echinoids.

8.4) In this study, porosity types are affected by the sedimentary environment, diagenesis and tectonic processes. In the high energy microfacies (Shoal and reef microfacies), primary porosity (Interparticle- and intraparticle) were formed that early cementation has decreased interpartile porosity, but dissolution has increased vuggy porosity during the early diagenesis stage. In the Lagoon and the open marine facies that have been affected by diagenesis, aragonite grains have been resolved and have created moldic porosity. Tectonic fractures in this facies are increased permeability. In the study section, cementation cause to decrease porosity, but dissolution, dolomitization and tectonic processes has led to form vuggy and fracture porosities. Generally, important factor in to being reservoir of Asmari Formation is porosities that was formed in the meteoric diagenesis stage and increased by tectonic fractures. As a result, porosity evaluation in the Asmari carbonate is controlled by sequence stratigraphy.

ACKNOWLEDGMENT

We would like to thank Dr. Mohammad reza Ghotbi Ravandi Assistant professor in Islamic Azad University, Zarand Branch, Zarand, Iran.

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