https://jssr.ui.ac.ir/?lang=en

Journal of Stratigraphy and Sedimentology Researches
E-ISSN: 2423-8007
Vol. 39, Issue 4, No. 93, Winter 2024, pp 37-52
Received: 16.01.2024 Accepted: 24.04.2024

Research Paper

Facies analysis, palaeodepositional environment and sequence stratigraphic framework of the Jahrum and Asmari formations, Fars Province, Zagros Basin, SW Iran

Roghayeh Fallah Bagtash *
Department of Petroleum and Sedimentary Basins, Faculty of Earth Sciences, Shahid Beheshti University, Tehran, Iran
r_fallah@sbu.ac.ir

Abstract
The Middle to Late Paleogene Zagros sedimentary basin witnessed the development of carbonate platforms teeming with large benthic foraminifera (LBF), exemplified by the Jahrum and Asmari formations in Fars Province, SW Iran. The LBF assemblage is dominated by *Nummulites* and *Orbitolites*, accompanied by smaller benthic foraminifera. In the present study, microfacies analysis, palaeoenvironmental reconstruction, and interpretation of depositional sequences/cycles in the late Eocene Jahrum and lower Miocene Asmari carbonates were conducted on the subsurface section of the Kuh-e-Mond Oil Field, located in Coastal Fars Province, within the Zagros Foreland Basin. The studied wells, designated as MD-07, MD-06, and MD-02, exhibit respective thicknesses of 33 to 130 m for the Asmari Formation and 382 to 517 m for the Jahrum Formation. The interpretation of facies suggests that these intervals precipitated along a low-angle ramp-type platform in a shallow-water setting. Nine distinct microfacies have been identified, representing tidal flats, lagoons, platform margins, and shallow open marine sub-environments. Based on the integration of petrographic studies and petrophysical logs (Gamma-ray log), three depositional sequences or cycles within the Jahrum Formation (SQ A, SQ B, SQ C) in the MD-07 well, and one depositional sequence or cycle within the Asmari Formation (SQ D) have been identified in the MD-07, MD-06, and MD-02 wells. These determined depositional sequences/cycles are not only influenced by global sea level fluctuations but also impacted by the regional tectonic history, including uplift and subsidence rates.
Keywords: Eocene, Miocene, Depositional cycle, Kuh-e-Mond anticline, Coastal Fars.

Introduction

Carbonate deposits from the Middle to Late Paleogene of the Zagros sedimentary basin, primarily represented by the Jahrum and Asmari formations, are found in both well-exposed surface outcrops and subsurface sections (Babazadeh and Cluzel 2022; Zulnoorian et al. 2023; Habibi et al. 2024). The Jahrum and Asmari formations serve as the primary hydrocarbon-bearing reservoirs, hosting numerous supergiant and giant hydrocarbon accumulations that account for over 90% of Iran's recoverable hydrocarbon resources (Sharland et al. 2001; Aqrawi et al. 2006; Habibi and Ruban 2017; Esrafili-Dizaji and Rahimpour-Bonab 2019).

In Tang-e Ab, located on Jahrum Mountain and serving as the type section of the Jahrum Formation, the strata consist of 467.5 m of dolostones, with 35.5 m of massive brown dolostone at the lower units, 162 m of thin-bedded dolostone in the middle parts, and 270 m of massive dolomitic limestones in the upper units (James and Wynd 1965). In the Kuh-e-Mond Oil Field and various other sections, such as the Khesht Oil Field, the Jahrum Formation is extensively dolomitized, especially in the lower and middle parts (Fallah-Bagtash et al. 2020). Consequently, the identification of primary texture and facies becomes challenging (Moallemi et al. 2010; Fallah-Bagtash et al. 2020; 2021). Nevertheless, limestone deposits rich in large benthic foraminifera are found in the middle and upper parts of the Jahrum Formation (e.g., Nummulites and Orbitolites) (Zohdi et al. 2013; Fallah-Bagtash et al. 2020).

The Asmari Formation in Tang-e Gel-e Tursh has a thickness of approximately 314 m, comprising brown to creamy limestones (Thomas 1948). These successions were deposited along a ramp-type platform, exhibiting a shallowing-upward trend from basinal to inner ramp deposits (Aqrawi et al. 2006; Omidpour et al. 2021; 2022; Fallah-Bagtash et al. 2020; 2021; 2022; Omidpour and Fallah-Bagtash 2022). Neritic calcareous sediments were deposited in the pre-Tethyan basin during the Paleogene, spanning from the Eocene to the Miocene (Philip 2003).

In Coastal Fars, the Early Miocene Gachsaran Formation conformably overlay the Asmari Formation and are underlain by the Jahrum Formation (Sadooni and Alsharhan 2019). The lower boundary of the Asmari Formation with the Pabdeh

*Corresponding author
Fallah Bagtash R. (2024). Facies analysis, palaeodepositional environment and sequence stratigraphic framework of the Jahrum and Asmari formations, Fars Province, Zagros Basin, SW Iran. Journal of Stratigraphy and Sedimentology Researches, 39(4): 37-51. https://doi.org/10.22108/jssr.2024.140390.1276

https://doi.org/10.22108/jssr.2024.140390.1276

Formation in Interior Fars province is conformable, whereas it is discontinuous in the Lurestan and Khuzestan areas (Sadooni and Alsharhan 2019).

Given the significant importance of the Asmari and Jahrum formations as oil reservoirs in the Zagros Basin, and recognizing the variations in thickness, lithology, fossil contents, facies, and age across the basin, detailed studies have been conducted on three wells in the Kuh-e-Mond Oil Field. The aim of this research is to understand of the palaeoenvironmental history of the Middle to Late Paleogene Zagros sedimentary basin in the Coastal Fars Province. It entails investigations into microfacies analysis, palaeoenvironmental reconstructions, sea-level fluctuations, and the depositional sequence/cycle framework of the Asmari and Jahrum formations.

Kuh-e-Mond HO field, the largest on-shore HO field in Iran, is a giant anticline located in the southwest of the country with a NW-SE trend (parallel to the Zagros orogenic belt) (Figure 2). This relatively symmetrical anticline is 90 km long and 16 km wide

Geological setting and stratigraphy

The Kuh-e-Mond Oil Field is situated in the Coastal Fars Province of the Zagros Fold-Thrust Basin in southwestern Iran, exhibiting a NW-SE trend parallel to the Zagros orogenic belt (Fig. 1A). It comprises a relatively asymmetrical anticline, measuring approximately 90 km long and 16 km wide, with a vertical collage of about 2500 m. It is located approximately 70 km southeast of Bushehr, and lies along the shorelines of the Persian Gulf (Shariatnia et al. 2013). This anticline is thought to be a drag-type structure, formed in response to the Kazerun Fault. Adjacent to the Kazerun Fault, this vast field generally exhibits simple and gentle folds, which developed into anticlinal trap structures during the late Miocene and Pliocene (Kamali and Rezaee 2003). This reservoir contains six billion barrels of heavy oil (API <10), with one-third of its oil located in the Jahrum and Asmari formations (Shariatnia et al. 2013). Hydrocarbon occurrence has been confirmed in three separate intensely fractured carbonate formations: the Asmari (Oligo-Miocene), Jahrum (Eocene) and Sarvak (Cretaceous) formations.

The Kuh-e-Mond Oil Field is characterized by a network of large interconnected fractures, predominantly developed in favorable areas. These fractures contribute to increased porosity, permeability, drainage, and petroleum accumulation (e.g., Bordenave 2008). They are formed due to tectonic activities during the evolution of the Neo-Tethys Basin, which ultimately led to the formation of the Zagros Sedimentary Basin. The convergent basin formation occurred from the late Cretaceous to the Late Miocene, driven by the subduction of the Arabian plate (from the northeast) beneath the Central Iranian plate (Shariatinia et al. 2013).

The Eocene Jahrum Formation in the Kuh-e-Mond area, with a thickness ranging from approximately 382 to 485 meters, primarily comprises highly fractured light brown dolostones exhibiting inter-crystalline, cavity, and fractured porosities. Towards the upper sections of this formation, some limestone layers are evident below the disconformity contact. On the other hand, the Asmari Formation, with a thickness ranging from approximately 33 to 130 meters, predominantly consists of dolostones, dolomitic limestones, and limestones. The age of the Asmari Formation in the Kuh-e-Mond Oil Field is considered to be Lower Miocene (Aquitanian) based on the paleolog of the studied wells. Conversely, the Jahrum Formation is believed to have been deposited during the Late Eocene, as indicated by the presence of Nummulites fabianii and Orbitolites complanatus (Moallemi et al. 2010).

General stratigraphy of the Arabian Plate during Middle Eocene to Oligocene

During the Lutetian to Priabonian stages (49-33.7 Ma), sedimentary deposits, including the Jadala succession in Syria and Iraq, the Dammam succession in Saudi Arabia, the Pabdeh and Jahrum formations in Iran, and their regional equivalents in adjacent areas, were deposited (Ziegler 2001) (Fig. 2). This time interval and the associated sediments correspond to the second depositional sequence within AP10 as identified by Sharland et al. (2001). This period indicates a gradual decline in eustatic sea level, as documented by Hag et al. (1988), suggesting that only small portions of the Arabian Plate may have been exposed. In the foredeep of the Zagros, sediments are equivalent to those found in the Pabdeh Formation (Hertig et al. 1995). Nevertheless, in Fars Province, the evaporitic conditions conducive to the deposition of the Sachun Formation have changed. The Dammam Formation has been deposited in the large area of eastern part of the Arabian Plate. The presence of Nummulites in the Dammam Formation suggests an age ranging from the late Ypresian to the Priabonian, as dated by Ziegler (2001).

The boundary between the Eocene and Oligocene periods delineates the AP10 and AP11 distinction as presented by Sharland et al. (2001). During the Rupelian to Chattian stages (33.7-23.8 Ma), the Pabdeh and Palani formations were deposited in Iran and Iraq, along with their regional equivalent formations in adjacent areas, as indicated by Ziegler (2001) (Fig. 3). AP11, characterized by major discontinuities and sedimentary hiatus, has covered most of the Arabian Shield since 34 Ma ago. Sediments were precipitated in the compressive foreland basin concurrently with the collision between the Arabian and Iranian plates, as described by Ziegler (2001). In the Oligocene, the sea level dropped, leading to the subaerial exposure of most of the inner parts of the basin (Fig. 3).

As Neo-Tethys rapidly closed, the foredeep of the Zagros along the northeastern part of the plate underwent significant narrowing, leading to the predominant deposition of carbonate sediments in the region. In the foredeep of the Zagros, the Asmari Formation has primarily deposited foraminiferous limestones with a micritic texture and light color, characterized by the presence of Nummulites and miliolids.

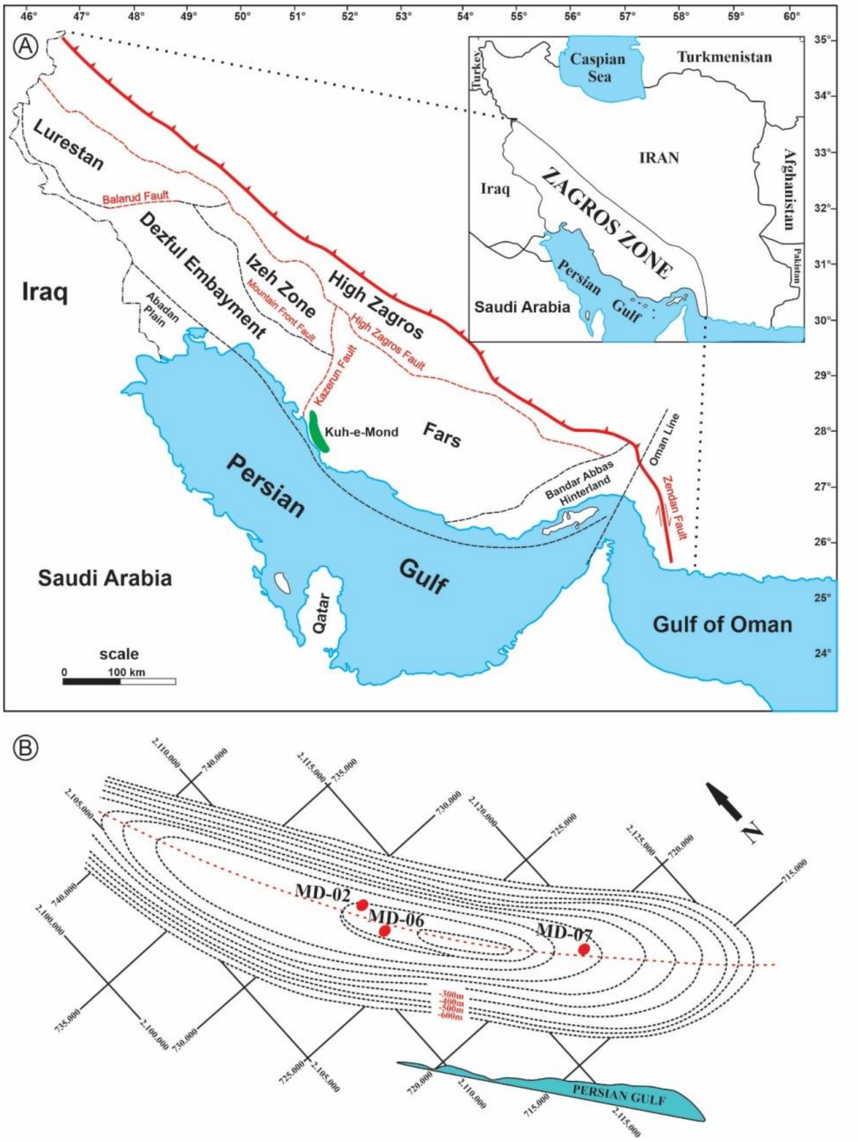

Fig 1- (A) The geological setting of the Kuh-e-Mond Oil Field in the Coastal Fars Province, adapted from Sepehr and Cosgrove (2004) and Heydari (2008); (B) Subsurface structural contour map along with studied wells in the Kuh-e-Mond Oil Field.

Material and methods

The present research involves thin section descriptions of samples collected from the Asmari and Jahrum formations from three wells identified as MD-02, MD-06, and MD-07 (refer to Fig. 1B). A total of 345 half-stained thin sections from the MD-02 well, 251 from the MD-06 well, and 125 from the MD-07 well were utilized to assess the distribution of facies within the studied intervals. Dickson's (1965) staining scheme was utilized to differentiate between dolomite and calcite in the thin sections. The rocks were then analyzed and classified according to Dunham's (1962) schemes and compared with facies belts and depositional models proposed by Wilson (1975) and Flügel (2010).

An integrated approach, incorporating petrographic techniques such as thin section studies, and petrophysical studies using Gamma-ray logs, is employed for the analysis and interpretation of depositional sequences, system tracts, and depositional sequences/cycles within the Asmari-Jahrum formations in the studied sections. This analysis is conducted based on Catuneanu's stratigraphic model (Catuneanu 2017). Due to the pervasive dolomitization of the formations studied in the Kuh-e-Mond Oil Field, it has not been possible to determine the system tracts and depositional cycles solely through petrographic studies. As a result, the defined stratigraphic sequences/cycles are verified using Cyclolog software. Cyclolog converts the gamma log into an Integrated Prediction Error Filter Analysis curve (INPEFA), which aids in the interpretation of depositional sequences and the identification of Milankovitch cycles (Nio et al. 2005; De Jong et al. 2006). The INPEFA curve encompasses all definitions and concepts outlined by Catuneanu (2017) for sequence stratigraphy interpretation.

The INPEFA curve exhibits intervals of positive and negative trends, which are separated by turning points,

https://doi.org/10.22108/jssr.2024.140390.1276

known as bounding surfaces. These turning points play a crucial role in evaluating facies development and well correlations. A major negative turning point (NBS) typically marks the beginning of a period of progradation and is often considered a candidate for a sequence boundary in sequence stratigraphy. Conversely, a major positive turning point (PBS) generally marks the onset of a shale or fine-grained interval. It frequently represents an onlap surface and can be interpreted as a flooding surface.

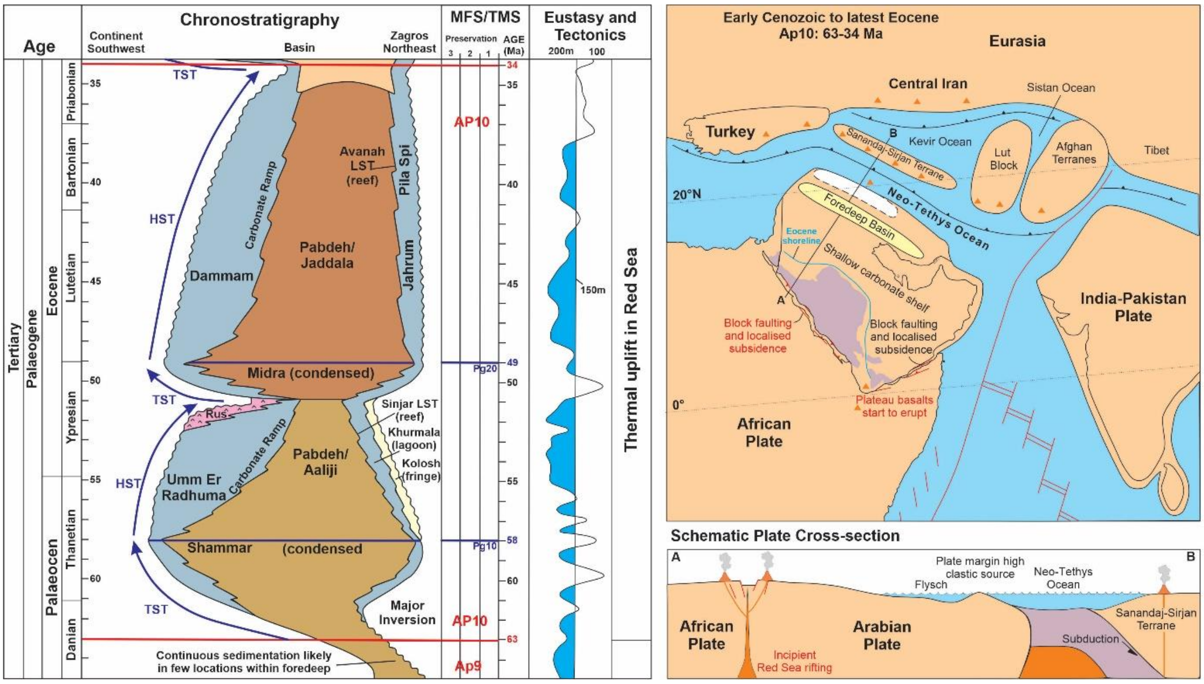

Fig 2-.Schematic Arabian Plate reconstruction and chronostratigraphic cross-section for AP10 (63-34 Ma) along the Zagros fore-deep and main tectonic events (Modified from Sharland et al. 2001).

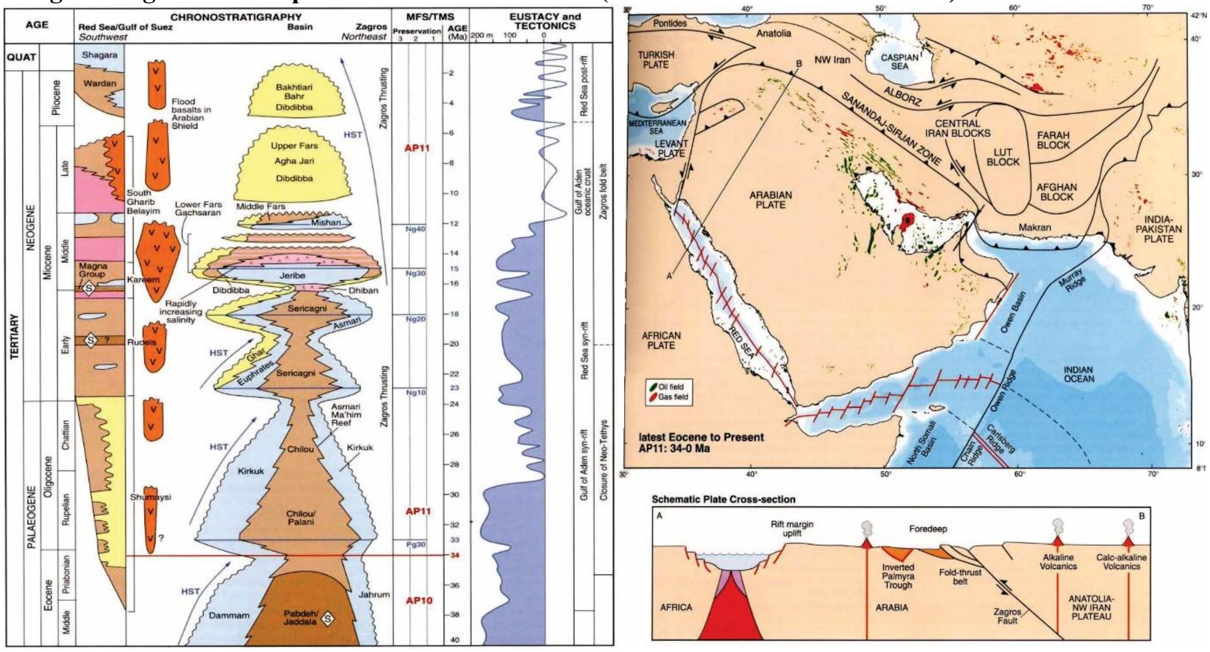

Fig 3- Schematic Arabian Plate reconstruction and chronostratigraphic cross-section for AP11 (34-0 Ma) (Modified from Sharland et al. 2001). **The final Zagros collision took place at the end of the Pliocene.**

https://doi.org/10.22108/jssr.2024.140390.1276

Results

Microfacies analysis

Microfacies Analysis of Asmari Formation in Kuh-e-Mond Oil Field

Examination of the Asmari thin sections from the studied wells reveals four principal microfacies (MF1 to MF4; see Figs. 4A to E). The lithostratigraphic column of the studied succession in these wells is presented in Figure 5.

MF1: Laminated to massive anhydrite

Description: Anhydrite deposits consist of massive to layered interlocked anhydrite crystals with aligned to semi-aligned designs (see Fig. 4A). In some cases, it is associated with fine crystalline dolomite. This microfacies lacks fossils and sedimentary structures.

Interpretation of depositional environment: Considering the width, vertical and lateral accumulation, and continuity of the anhydrite layers, it can be inferred that these deposits accumulated in a limited saline brine environment (Vaziri-Moghaddam et al. 2010). Supratidal/sabkha anhydrites typically form in a shallowing upward environment and commonly have a thickness ranging from 1 to 10 meters (Warren 2006). Similar microfacies have been reported from the supratidal setting in the Shadgan Oil Field, Dezful Embayment by Omidpour et al. (2021a), as well as by Fallah-Bagtash et al. (2020; 2022) in the Khesht Oil Field, Fars Province.

MF2: Dolomudstone

Description: Dolomudstone is characterized by a dolomicritic matrix with scattered silt-sized quartz grains occurring at a frequency of approximately 10% (see Fig. 4B). Sparse anhydrite crystals and nodules are occasionally present (see Fig. 4C). Fossils are rare in this microfacies.

Interpretation of depositional environment: In general, the presence of fine-crystalline dolomite and fine-grained particles, along with evaporite minerals such as gypsum and anhydrite, and the absence of fossils, suggest deposition in the upper intertidal zone of an inner ramp environment characterized by high salinity and relatively low energetic conditions (Jafarian et al. 2017; Omidpour et al. 2021; Omidpour and Fallah-Bagtash 2022). The siliciclastic materials may have originated from either erosion of the basin floor in the tidal flat or wind-blown silt (Adabi et al. 2016).

MF3: Peloid - bioclast dolowackestone

Description: This microfacies consists of bioclastic components (>20%), including brachiopods, green algae, echinoids, miliolids, and other dolomitized porcelaneous foraminifers, along with small amounts of dolomitized peloids (see Fig. 4D). These components are embedded within a dolomicrite to dolomicrosparite matrix (66%). In most samples, only the relics of peloids and bioclasts can be recognized as fogged or ghost structures.

Interpretation of depositional environment: The low fauna diversity, presence of peloids, and a lime muddy matrix suggest deposition in a shallow, restricted lagoon with limited connection to the open marine environment (Fallah-Bagtash et al. 2021; Omidpour et al. 2021).

MF4: Bioclast - imperforate foraminifer dolowackestone/dolopackstone

Description: Imperforate foraminifers like *Austrotrillina* sp., *Archasias* sp., *Peneroplis* sp., *Meandropsina* sp., *Dentritina rangi*, miliolids, *Textularia* sp., *Discorbis* sp., and *Quinqueloculina* sp. along with bivalves, echinoids, bryozoans, gastropods, and *Lithophyllum* sp. are the main biogenic fauna (see Fig. 4E). Moderately well-sorted, rounded, and dolomitized peloids (0.2-0.5 mm) constitute the non-biogenic fauna (see Fig. 4E). In some areas, only ghost remnants of bioclasts remain, a consequence of widespread dolomitization.

Interpretation of depositional environment: The high diversification of imperforate benthic foraminifera (miliolids) within a muddy matrix indicates deposition in a restricted lagoon, while the low diversity of biotic fauna species suggests accumulation in a shallow, restricted lagoon with low hydraulic energy, slow water circulation, and hypersalinity (Fallah-Bagtash et al. 2021; Omidpour et al. 2021). Other factors indicating the energy of the environment include the preservation of foraminifera and the presence of micritic envelopes on bioclasts, indicative of the long-term placement of skeletal grains in quiet, calm water conditions (Mishra and Tiwari 2006).

Microfacies Analysis of the Jahrum formations in Kuh-e-Mond Oil Field

The Jahrum Formation in the Kuh-e-Mond Oil Field exhibits almost complete dolomitization, presenting challenges for facies analysis compared to other areas of the Zagros Basin (Fallah-Bagtash et al. 2020). To address this difficulty, this formation has been compared with equivalents documented in various papers to evaluate the distribution pattern of depositional facies (Moallemi et al. 2010; Fallah-Bagtash et al. 2020). The studied thin sections of the Jahrum Formation indicate five principal microfacies (MF5 to MF9; see Figs. 4F to M):

MF5: Orbitolites - Nummulites dolowackestone/dolopackstone

Description: Both *Nummulites* and *Orbitolites* are the major constituents of this microfacies. Additionally, other benthic foraminifers such as miliolids, *Elphidium* sp., and Austrotrilina sp. are present (see Figs. 4F and G). Peloids, although less frequent, contain non-biogenic content.

Interpretation of depositional environment: The presence of *Orbitolites* and large *Nummulites* assemblages suggests a restricted shallow setting. Therefore, based on their association with other small benthic foraminifers, it is plausible to consider a semi-restricted lagoonal setting in the leeward parts of a carbonate shoal for the deposition of this microfacies (Geel 2000).

Equivalent microfacies has also been identified by Khatibi Mehr and Adabi (2014), Moalemi et al. (2010), and Fallah-Bagtash et al. (2020). According to findings of Moalemi et al. (2010), the Orbitolites - Nummulites dolowackestone/dolopackstone microfacies in Bushehr Field forms the upper Jahrum Formation in Fars Province. Similarly, in the Khesht Oil Field, this microfacies comprises the upper Jahrum succession, with the Asmari Formation directly overlying this microfacies (Fallah-Bagtash et al. 2020).

MF6: Nummulites dolopackstone/dolograinstone

Description: This microfacies comprises large *Nummulites*, constituting 30 to 40% of the assemblage, within a packstone to grainstone texture, set in a dolomitized matrix. The benthic

https://doi.org/10.22108/jssr.2024.140390.1276

foraminifers have undergone diagenetic alterations, and have been replaced by dolomite (see Fig. 4H).

Interpretation of depositional environment: According to Zamagni et al. (2008), large *Nummulites* with elongated crusts are deposited in front of the carbonate shoal below the storm wave base, whereas large *Nummulites* with thick crusts around the carbonate shoal and small *Nummulites* with thick crusts are deposited in the back shoal setting. Therefore, the deposition of this microfacies could range from the upper parts of the mid-ramp to the shoal setting due to the presence of large *Nummulites* with elongated and thick crusts within a packstone to grainstone texture.

MF7: Echinoid - Nummulites dolowackestone

Description: The predominant fauna of this microfacies consists of *Nummulites* with a frequency of approximately 15 to 20%, along with echinoid fragments, within a dolomitic matrix (see Fig. 4I). *Discocyclina* is present but with low frequency. However, due to the pervasive dolomitization of the Jahrum Formation, especially in the lower parts of the studied intervals, these components are difficult to distinguish in thin sections.

Interpretation of depositional environment:

The depositional environment of the *Nummulites* facies can vary from the proximal outer ramp to the mid-ramp, depending on the type of accompanying counterparts. It is classified as an outer ramp if accompanied by *Discocyclina* or *Operculina*; otherwise, its deposition is attributed to the mid-ramp setting (Taheri et al. 2008). The high percentage of large benthic foraminifers, such as different species of elongated flat *Nummulites*, with low amounts of elongated *Discocyclina*, and the presence of open marine fauna like echinoids in a muddy matrix, suggest deposition may have occurred in a mid-ramp environment with moderate to low energetic conditions (Geel 2000; Khatibi Mehr and Adabi 2014). Equivalent microfacies have also been identified by Sadeghi et al. (2015) in the Jahrum anticline, by Khatibi Mehr and Adabi (2014) in the Gach-Mountain outcrop, and by Fallah-Bagtash et al. (2020) in the Khesht Oil Field, Fars Province.

MF8: Pelagic wackestone/mudstone

Description: The main components of this microfacies include planktonic foraminifera such as Globigerina sp. (see Fig. 4J and K). The diversity of planktonic foraminifera species suggests that it represents the Pabdeh-Jahrum transitional zone (Fallah-Bagtash et al. 2020). Additionally, echinoid fragments, thin shells of ostracods, brachiopods, and glauconite are scattered within a muddy matrix (see Fig. 4L).

Interpretation of depositional environment:

The presence of planktonic foraminifera within a lime mud, coupled with the absence of bioturbation, suggests formation in the distal outer ramp beneath the storm wave base (Kakemem et al. 2016). Furthermore, the presence of glauconite and pyrite crystals indicates a slow sedimentation rate and reducing conditions with low oxygen levels at greater depths in the open marine environment.

MF9: Bioclast dolostone

Description: Portions of the studied intervals exhibit dolomicrofacies/dolostones with intensive dolomitization, rendering their internal structure and components indistinguishable (see Fig. 4M). The dolostone displays multi-stage dolomitization, characterized by numerous fabric-destructive dolostones. The remnants of the original components can be identified as fogged or ghost structures.

Interpretation of depositional environment: Due to the pervasive dolomitization and the indistinguishable internal structure of the constituent particles, this microfacies could not be confidently attributed to any of the existing microfacies and related depositional environments. However, based on the abundance of medium to coarse crystalline dolomite, it is inferred that bioclastic dolostones were formed during late diagenesis, particularly in a shallow burial environment, through recrystallization or replacement of primary dolomites (Fallah-Bagtash et al. 2022).

https://doi.org/10.22108/jssr.2024.140390.1276

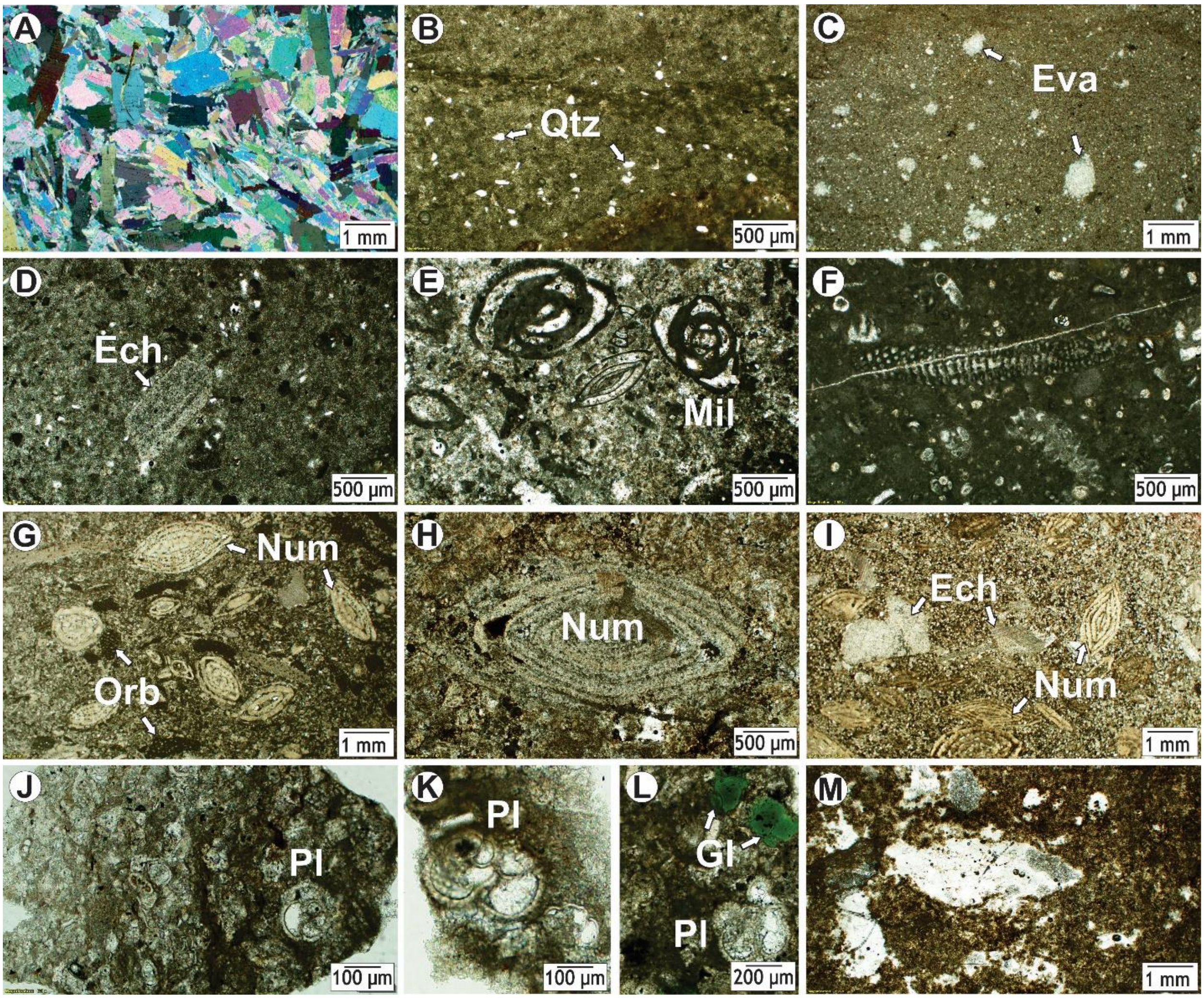

Fig 4- Microfacies of Jahrum and Asmari formations.
(A) Laminated to massive anhydrite (MF1, Asmari Fm. MD-06, 320 m, XPL);
(B) Dolomudstone with scattered silt-sized quartz grains (Qtz) (MF2, Asmari Fm. MD-02, 181 m, PPL);
(C) Dolomudstone with sparse anhydrite nodules (Eva) (MF2, Asmari Fm. MD-02, 200 m, PPL);
(D) Peloid - bioclast dolowackestone (MF3) (MF3, Asmari Fm. MD-06, 392 m, PPL);
(E) Bioclast - imperforate foraminifer dolowackestone/dolopackstone (MF4, Asmari Fm. MD-02, 250 m, PPL);
(F) *Orbitolites - Nummulites* dolowackestone/dolopackstone (MF5, Jahrum Fm. MD-06, 534 m, PPL);
(G) *Orbitolites - Nummulites* dolowackestone/dolopackstone (MF5, Jahrum Fm. MD-06, 420 m, PPL);
(H) *Nummulites* dolopackstone/dolograinstone (MF6, Jahrum Fm. MD-06, 486 m, PPL);
(I) Echinoid - *Nummulites* dolowackestone (MF7, Jahrum Fm. MD-07, 510 m, PPL);
(J and K) Pelagic wackestone/mudstone, Planktonic foraminifera (Pl) is the main constituent, (MF8, Jahrum Fm. MD-06, 718 m, PPL);
(L) Glauconite (Gl) in pelagic wackestone/mudstone (MF8, Jahrum Fm. MD-06, 718 m, PPL);
(M) Bioclast dolostone, the molds of bioclasts (maybe a *Nummulites*) are visible (MF9, Jahrum Fm. MD-06, 479.8 m, PPL).

https://doi.org/10.22108/jssr.2024.140390.1276

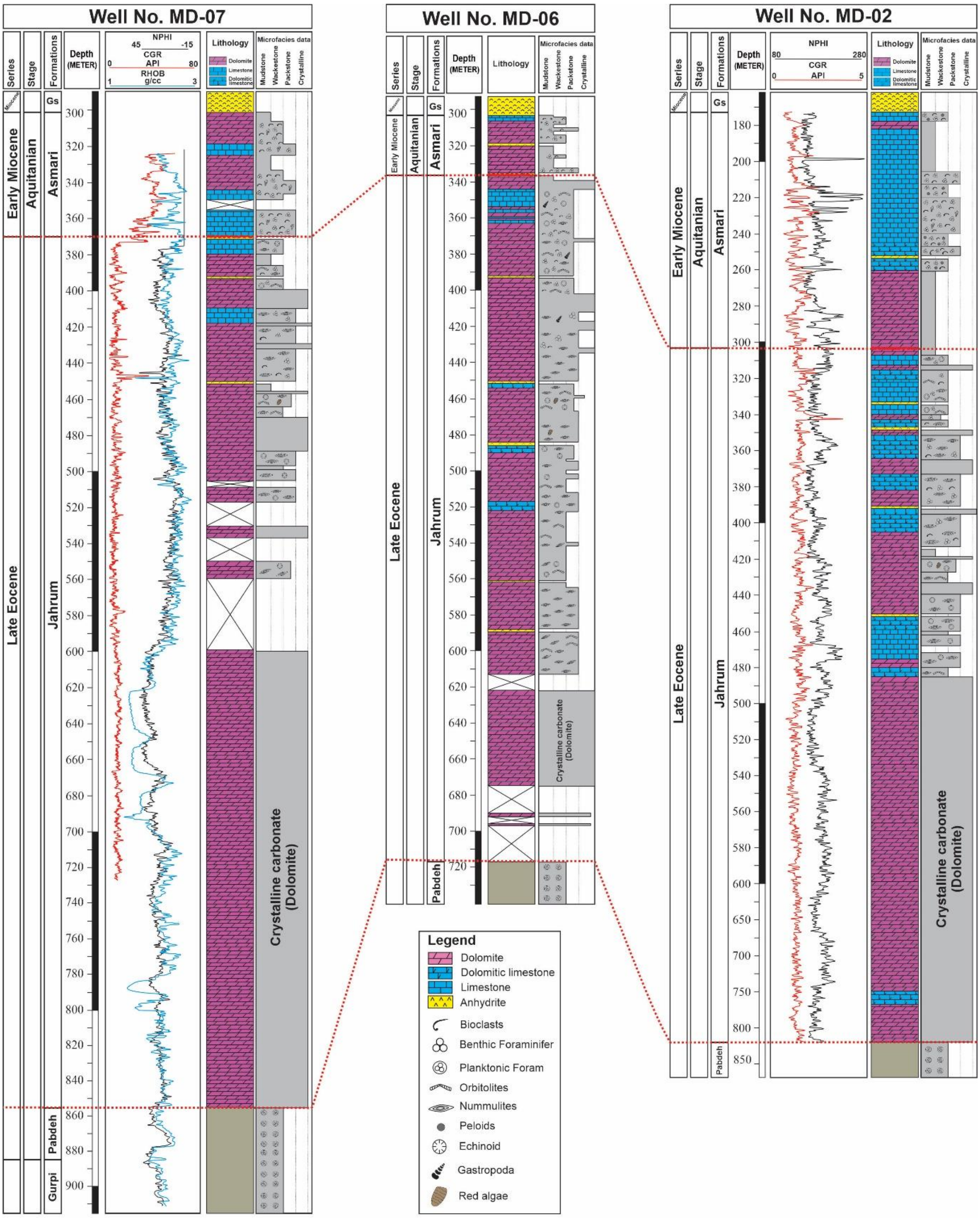

Fig 5- Lithostratigraphic column of the Jahrum and Asmari successions in the MD-07, MD-06, and MD-02 wells.

Paleodepositional environment

Previous studies have indicated that the Jahrum Formation was deposited along a shallow carbonate platform (Nadjafi et al. 2004; Adabi et al. 2008; Moallemi et al. 2013; 2014; Parvaneh Nejad Shirazi et al. 2014; Fallah-Bagtash et al. 2020). The Jahrum Formation is characterized by the presence of large benthic foraminifera, notably *Nummulites*, *Orbitolites,* and Discocyclina, which serve as primary biological components.

https://doi.org/10.22108/jssr.2024.140390.1276

Consequently, numerous researchers have relied on these large hyaline foraminifera from the Eocene period as fundamental elements for paleoenvironmental and paleoecological interpretations (Beavington-Penney et al. 2006; Adabi et al. 2008; Kakemem et al. 2016; Kamran et al. 2021; Kakemem et al. 2023).

The high uniformity observed in the layers bearing large benthic foraminifera within massive sequences in the Jahrum Formation suggests low facies diversity. This uniformity, coupled with the absence of siliciclastic facies and the widespread extension of carbonate platforms within Fars Province during the accumulation period of the Jahrum Formation, provides evidence for a stable sedimentation rate and tectonic stability throughout the Middle to Late Eocene (Moallemi et al. 2010; Fallah-Bagtash et al. 2020). Comparative analysis of sedimentation patterns between the Jahrum Formation and time-equivalent formations in the Arabian plate, such as the Dammam and Sib Formations, suggests a broad paleoenvironmental connection between the northern regions of the present-day Persian Gulf and the central areas of the Arabian platform (Ziegler 2001; Boukhary et al. 2006; Maziqa et al. 2024). Both formations appear to have been deposited in a passive margin on the southern side of Neo-Tethys.

The distribution pattern of identified facies within the Asmari Formation suggests significant differences in sedimentary basin conditions and thickness in Fars Province compared to other segments of the Zagros Sedimentary Basin (Taheri et al. 2008; Vaziri-Moghaddam et al. 2010; Mohseni et al. 2016; Fallah-Bagtash et al. 2021; Omidpour et al. 2021; Omidpour and Fallah-Bagtash 2022; Omidpour et al. 2023). The Asmari Formation in Fars Province exhibits less thickness and facies diversity compared to other segments of the Zagros Sedimentary Basin (Moallemi et al. 2010; Fallah-Bagtash et al. 2020). The results of this study indicate that only lagoonal and tidal flat facies associations are present in the Asmari Formation in Coastal and Sub-coastal Fars Province. This suggests that the formation was deposited on a shallow ramp-type platform with lagoon to tidal flat sub-environments. Notably, no evidence of shoal, reef, and open marine facies typically found in other segments of the Zagros Sedimentary Basin was detected (Omidpour and Fallah-Bagtash 2022). Lagoonal facies were deposited directly on the Jahrum Formation with erosional discontinuity, followed by tidal flat facies in a gradually upward shallowing trend towards the upper Asmari Formation. The minimum thickness of the Asmari Formation is observed in the MD-06 well, located at the shallowest part of the ancient platform in the central area of the Kuh-e-Mond Oil Field. Thickness increases towards the MD-02 and MD-07 wells. Based on Soltani et al. (2013) research, the Asmari Formation of the west and southwest Iran was deposited on a carbonate ramp contrary to deposition of the age-equivalent Kirkuk Group which has well-developed shelfal coral reef (Fig. 6).

The interpretation of a carbonate ramp-type platform for the accumulation of Asmari and Jahrum carbonates in the Kuh-e-Mond Oil Field, Coastal Fars Province, is supported by various factors. These include the presence of a large benthic foraminifera assemblage, low facies diversity, gradual changes in facies, absence of turbidites, slide, and slump facies typically associated with steep slopes (Kakemem et al. 2016; Omidpour et al. 2021; 2023), the lack of coated grains such as oncoids, pisoids, and aggregates (Flugel 2010), abundance of micrite in all identified microfacies (Adabi et al. 2008; Omidpour et al. 2021), and comparison with models proposed by Wilson (1975) and Flugel (2010) (Fig. 7).

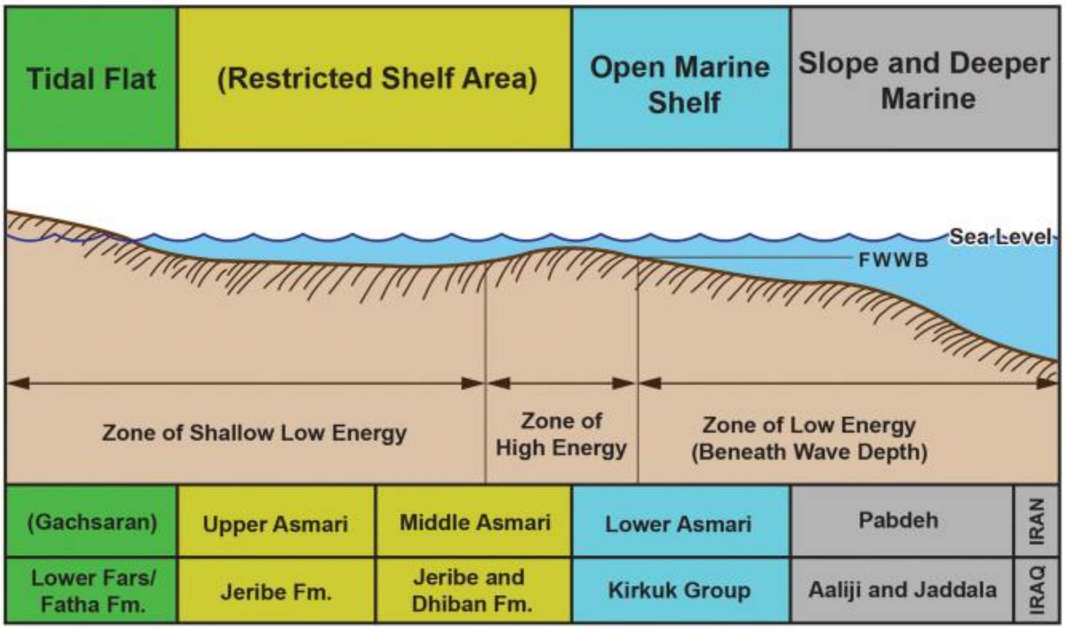

Fig 6- Main depositional environments of the Asmari Formation in Iran and Iraq (Modified after Soltani et al. 2013).

Due to their location at the shallowest part of the carbonate ramp and pervasive destructive dolomitization in lower parts, it is not possible to identify the carbonate ramp type (distally steepened or homoclinal) in the studied intervals. Microfacies distribution and related sub-environments indicate that the main settings for the deposition of the Jahrum and Asmari microfacies in Coastal Fars are the inner and mid ramp (Fig. 7). The inner ramp is characterized by the most varied depositional setting in the studied successions. In mid-ramp facies, *Nummulites* and

Discocyclina are the dominant benthic foraminifers, whereas inner ramp facies are characterized by *Nummulites* and *Orbitolites* along with a high diversification of other benthic forams like *Austrotrillina* sp., *Archasias* sp., *Peneroplis* sp., *Borelis* sp., *Meandropsina* sp., *Dentritina rangi*, miliolids, *Textularia* sp., *Valvulina* sp., *Discorbis* sp., *Quinqueloculina* sp., and *Bigenerina* sp.

During the Late Eocene, the deposition of the Jahrum Formation followed a specific order within a shallow basin. Initially, MF8 (pelagic wackestone/mudstone) represented a gradual transition zone between the Pabdeh and Jahrum formations in deeper parts of the platform. This was followed by the deposition of MF7 (echinoid - *Nummulites* dolowackestone) in a mid-ramp setting characterized by moderate- to low-energetic open marine conditions. MF6 (*Nummulites* dolopackstone/dolograinstone) then formed, representing either the carbonate shoal or the margin of the platform above the Fair-Weather Wave Base (FWWB). Finally, towards the late Eocene, MF5 (*Orbitolites* - *Nummulites* dolowackestone/dolopackstone) was deposited at the upper Jahrum Formation in a restricted lagoon setting of an inner ramp (Fig. 7).

According to the paleolog of the Kuh-e-Mond Oil Field, the Asmari Formation was deposited during the Early Miocene (Aquitanian) period. During this time, inner ramp conditions predominated due to basin uplifting (Mohseni et al. 2016). Consequently, the Asmari succession mainly accumulated in the inner ramp, comprising three distinct sub-environments: a restricted lagoon, intertidal, and supratidal settings (Fig. 7). MF4 (Bioclast, imperforate foraminifer dolowackestone/dolopackstone) and MF3 (Peloid - bioclast dolowackestone) represent the low-energy depositional conditions characteristic of a restricted lagoon. The dominance of benthic foraminifers, especially miliolina sp., suggests warm shallow waters typical of tropical and subtropical environments (Gonera 2012). MF2 (Dolomudstone) and MF1 (Laminated to massive anhydrite) represent the tidal flat setting of the inner ramp, characterized by low-energy conditions. Additionally, the prevalence of evaporitic and dolomicritic-dominated tidal flats suggests shallow water with hot and arid conditions. Mixed evaporitic carbonate ramp-type platforms typically form at passive margins with moderate slopes (Badenas and Aurell 2001). The prevailing subaerial conditions resulting from abrupt fluctuations in sea level (fall) led to the precipitation of the evaporitic Gachsaran (Heydari 2008).

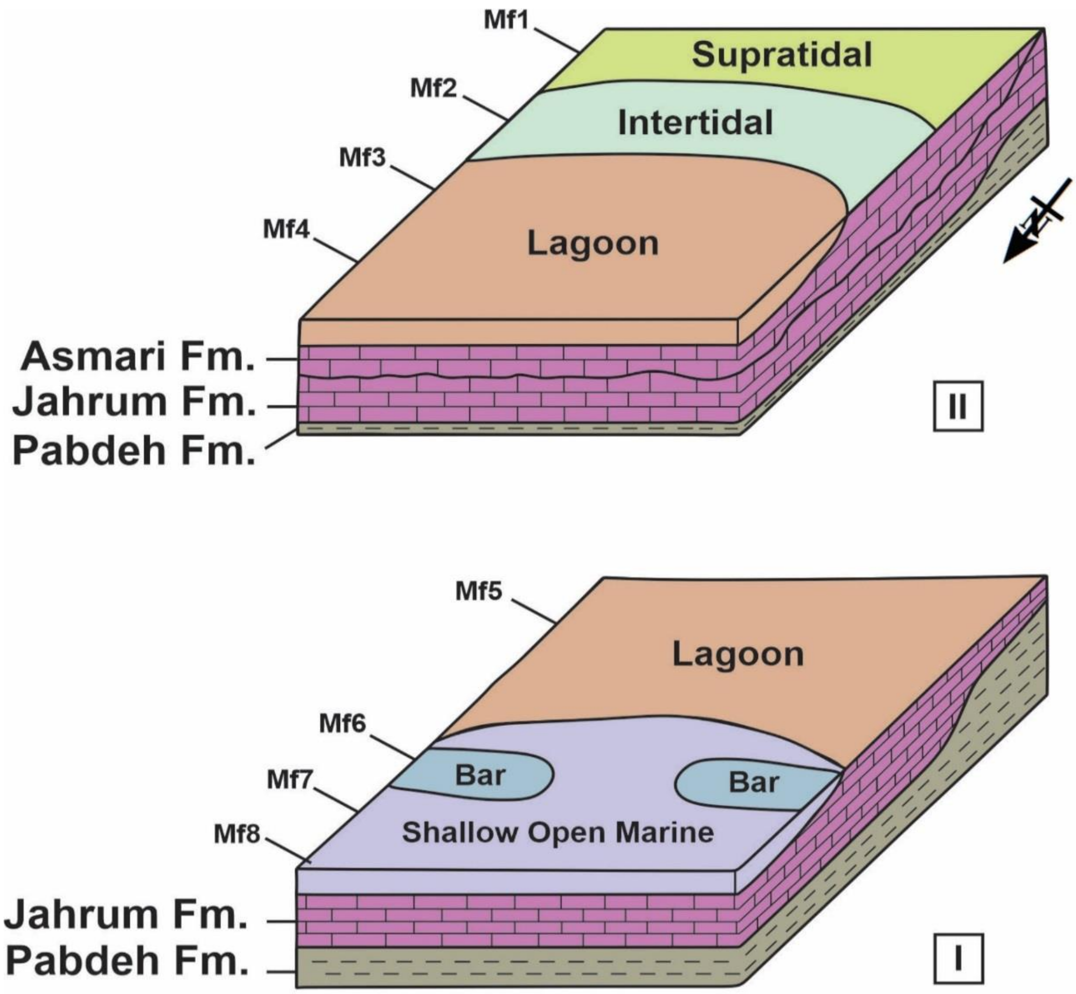

Fig 7- Block diagrams showing depositional environments of Jahrum (I) and Asmari (II) formations in Kuh-e-Mond anticline.

https://doi.org/10.22108/jssr.2024.140390.1276

Sequence stratigraphy

To determine the stratal surfaces and conduct sequence stratigraphic analysis of the Asmari and Jahrum successions, a gamma log was utilized as input data in Cyclolog software. Through the integration of petrographic studies and petrophysical logs, three depositional sequences or cycles were identified within the Jahrum Formation (SQ A, SQ B, SQ C) in the MD-07 well. Additionally, one depositional sequence or cycle was recognized for the Asmari Formation (SQ F) in the MD-07, MD-06, and MD-02 wells (Fig. 8).

In MD-07, the first depositional sequence or cycle of the Jahrum Formation (SQ A) exhibits a lithology primarily characterized by dolostones. This sequence comprises two system tracts, namely the Transgressive Systems Tract (TST) and the Highstand Systems Tract (HST). It is differentiated from SQ B by the presence of Sequence Boundary A (SB A) or a positive bounding surface (PBS). Within this sequence, the TST is situated within the underlying Pabdeh Formation, discernible by the increasing or positive trend observed in the Integrated Prediction Error Filter Analysis (INPEFA) curve. The TST predominantly consists of distal outer ramp microfacies (MF8) characterized by dolomitic lithology.

It is noteworthy that the thickness of the Pabdeh Formation in MD-07 is approximately 30 meters. Consequently, it can be inferred that the deposition of the Jahrum Formation in the Kuh-e-Mond Oil Field commenced from the beginning of the Late Eocene, and the transition from the Pabdeh to the Jahrum Formation (from the Middle Eocene to the Late Eocene) occurred gradually. The Maximum Flooding Surface (MFS) A is identified by the presence of a negative bounding surface (NBS), which is situated near the boundary between the Pabdeh and Jahrum formations. The Highstand Systems Tract (HST), with a thickness of 116 meters in MD-07, is characterized by outer to mid-ramp microfacies (MF7) and exhibits a negative trend in the INPEFA curve.

The second and thickest depositional sequence or cycle of the Jahrum Formation (SQ B) comprises two system tracts (TST and HST) characterized by dolomitic lithology and has a total thickness of 238 meters in the MD-07 well. The TST is marked by a positive shift in the INPEFA curve, culminating at the negative bounding surface (NBS) or Maximum Flooding Surface (MFS) B at a depth of 608 meters. Conversely, the HST exhibits a negative trend in the INPEFA curve, terminating at the SB B or the positive bounding surface (PBS). In MD-07, the thickness of the HST is approximately 144 meters, while the TST measures 94 meters in thickness. The shallowing-upward facies trend within this sequence comprises outer to mid-ramp carbonate facies associations (MF7 and MF6).

The youngest and uppermost depositional sequence of the Jahrum Formation is SQ C, which solely comprises the TST system tract exhibiting a positive trend in the INPEFA curve. With a thickness of about 144 meters, the TST encompasses mid to inner ramp facies (MF6) at the lower part and lagoonal facies (MF5: *Orbitolites* - *Nummulites* dolowackestone/dolopackstone) at the upper parts, displaying retrogradation stacking patterns. While the dominant lithology of this sequence is dolostones, in some sections, it exhibits limited calcareous content. The TST terminates upwards at SB C or the positive bounding surface (PBS), which corresponds to the erosional boundary of the Jahrum Formation with the Asmari Formation. Notably, its HST has been completely eroded.

The Asmari Formation consists of only one depositional sequence (SQ D) with an Aquitanian age, which overlies SQ C of the late Eocene Jahrum Formation with an erosional contact. In the MD-07 well, SQ D comprises solely the TST system tract, displaying a positive shift in the INPEFA graph. Consequently, the TST of this sequence, characterized by dominant dolostones alternating with limestones, terminates at the MFS D, coinciding with the upper boundary of the Asmari Formation with the underlying Gachsaran Formation. The total thickness of TST is about 69 meters in the MD-07, approximately 33 meters in the MD-06, and 130 meters in the MD-02. The TST primarily comprises an alternation of high diversification of imperforate benthic foraminifera in lagoonal microfacies (MF3 and MF4), along with upper intertidal (MF2) and supratidal facies (MF1). Exploration of its HST is required within the evaporitic Gachsaran Formation.

https://doi.org/10.22108/jssr.2024.140390.1276

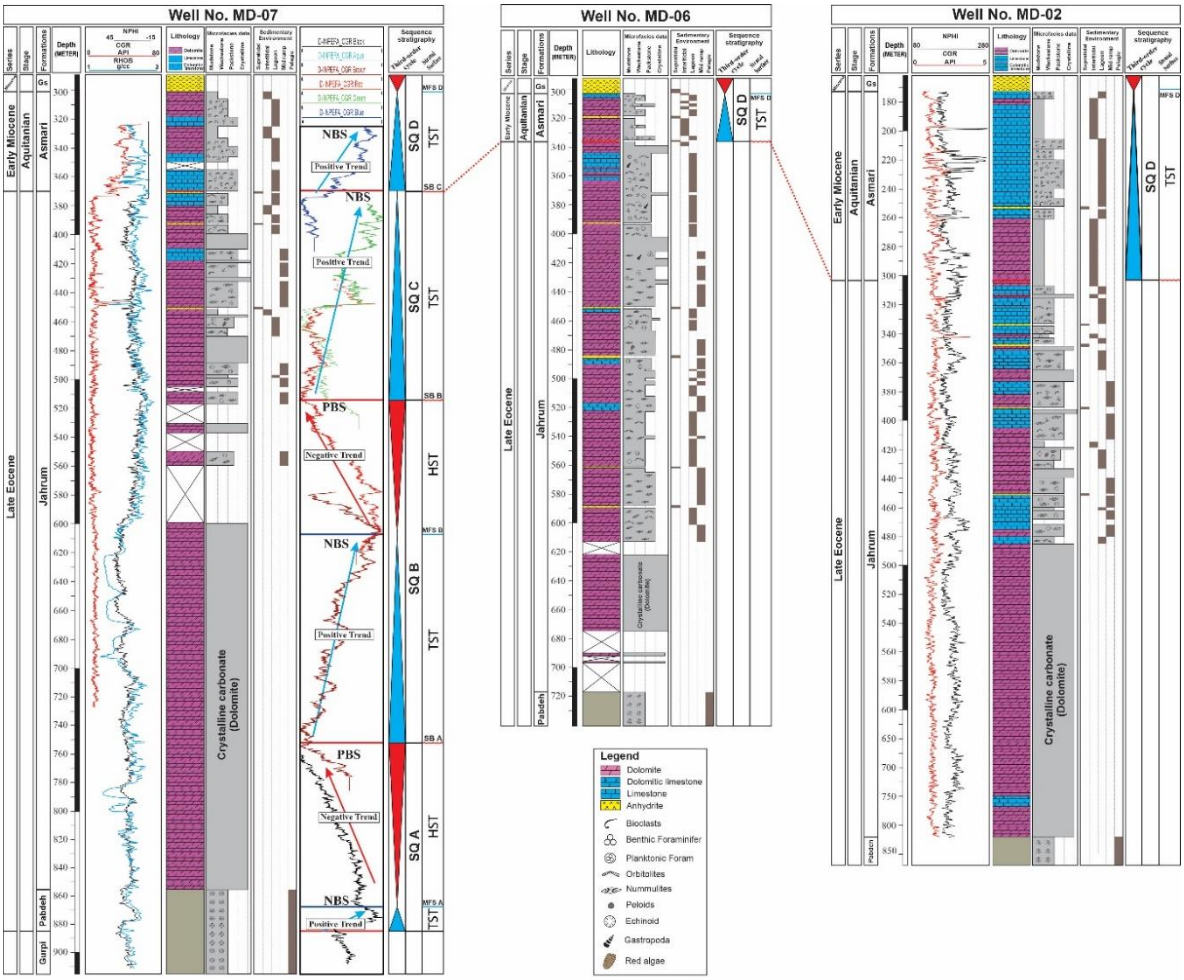

Fig 8- The INPEFA correlation graphs of the Jahrum and Asmari succession in MD-07, MD-06 and MD-02 wells. (SB = red lines; MFS = blue lines; PBS = positive bounding surface; NBS = negative bounding surface).

Discussion

The structural investigation of the Arabian Plate conducted by Sharland et al. (2001) identified 11 tectonostratigraphic Mega sequences (TMS) from the Cambrian to the present. According to their findings, AP10 spans from the Early Paleocene to the late Eocene (63–34 Ma) and encompasses two '2nd' depositional sequences (Vail et al. 1977). It's noted that the Jahrum Formation in the Fars Province, along with its time-equivalent interval such as the Dammam Formation in the Arabian Plate, corresponds to the second highstand systems tract (HST) of AP10 (Fig. 2). The Paleogene Sea, following Late Cretaceous movements, extended widely across the Zagros Sedimentary Basin. Within this basin, various sedimentary formations were deposited in different coastal sub-environments. These include the siliciclastic Sachun Formation, the carbonaceous Jahrum Formation in shallower waters, and the shaly Pabdeh Formation in deeper waters.

The absence of a lowstand systems tract (LST) in all depositional sequences of the Jahrum Formation suggests that these sequences were deposited in passive continental margins, where siliciclastic facies resulting from tectonic activities are typically lacking. Instead, each depositional sequence represents a complete cycle of sea level fluctuation on a regional scale. Sediment supply rate and basin subsidence are believed to have been the primary factors influencing the formation of these sequences, as noted by Moallemi et al. (2010).

The investigation conducted in this research highlights that the thickest occurrence of the Jahrum Formation is observed in the Kuh-e-Mond Oil Field, Coastal Fars, which represents the section nearest to the ancient coastline of the Jahrum sedimentary basin. This suggests that high sediment supply occurred in the warm waters within the carbonate platform, particularly in its shallow parts. As one moves perpendicular to the Zagros trend, the thickness of the Jahrum Formation gradually decreases. In the Interior Fars region, for example, the thickness of this formation is less than half of that observed in the Kuh-e-Mond Oil Field. In contrast, in the central section of Zagros, including the Interior Fars, the deposition of shaly sediments from the Pabdeh Formation occurred during the Eocene, with no trace of the Jahrum Formation. This observation is supported by previous studies (Moallemi et al. 2010; 2014; Mahmoodabadi 2014; Fallah-Bagtash et al. 2020). Comparative analysis of the Jahrum Formation facies within the studied sections reveals notable differences. In the Kuh-e-Mond Oil Field, the facies comprising this formation are indicative of shallower environments, primarily mid to inner ramp settings. However, as one moves from Kuh-e-Mond towards the Interior Fars region, the facies shift towards deeper environmental conditions, predominantly representing mid and outer ramp settings (Nadjafi et al. 2004; Moallemi et al. 2010; 2014; Mahmoodabadi 2014; Fallah-Bagtash et al. 2020). During the Pyrenean Orogeny, which was synchronous with the Paleogene period, there was a widespread regression of the Paleogene Sea. This regression resulted in the exposure of the Jahrum platform, characterized by discontinuities at the upper contact of the Jahrum Formation. However, in certain regions such as southwest Lurestan, Khuzestan, and Interior Fars, deep basinal sediments of the Pabdeh Formation and its equivalents were deposited.

The Pabdeh, Asmari, and Gachsaran formations are encompassed within the final mega sequence of the Arabian Plate, referred to as AP11, which spans from the Oligocene to the Pliocene age, as documented by Sharland et al. (2001). The AP11 mega sequence, which formed over a period of approximately 34 million years, is characterized by a package of sediments situated between two major unconformities: the initiation of Red Sea rifting (Gaff et al. 1995) and the present-day morphology of the Arabian Plate (Sharland et al. 2001).

AP11 is further subdivided into three 'second-order' depositional sequences based on the eustatic curve presented by Haq et al. (1988), as outlined by Vail et al. (1977). The early Miocene Asmari succession in the southeastern Zagros Sedimentary Basin and its time equivalent interval occur concurrently with the second highstand system tract (HST) within AP11 (see Fig. 3). During the Oligocene (Rupelian and Chattian), the Asmari succession did not accumulate in the Kuh-e-Mond Oil Field due to subaerial exposure of the area. However, during the early Miocene (Aquitanian), with the gradual rise of sea level, the Asmari succession was deposited within a single depositional cycle exhibiting a shallowing-upward trend in the Kuh-e-Mond Oil Field, coinciding with the conclusion of the second HST in AP11. Indeed, the abrupt changes in sea level, resulting in a fall, facilitated the formation of subaerial conditions and the deposition of the evaporitic Gachsaran Formation in a restricted sabkha setting, as noted by Heydari (2008). Consequently, the majority of the highstand system tract (HST) in Sequence A (SQ A) is formed within the Gachsaran Formation.

Conclusions

In the Kuh-e-Mond area of Fars Province, the Late Eocene Jahrum Formation, with a thickness ranging from approximately 382 to 485 meters, predominantly comprises fractured light brown dolostones with interspersed thin-layered limestones. In contrast, the Early Miocene Asmari Formation, with a thickness ranging from approximately 33 to 130 meters, is primarily composed of dolostones, dolomitic limestones, and limestones.

Sedimentological and petrographic evidence has allowed for the identification of eight evaporite-carbonate microfacies and one diagenetic microfacies within the Jahrum and Asmari successions. These microfacies were deposited in shallow-water carbonate ramp platforms, with the main facies occurring in inner to mid-ramp settings.

The integration of thin section data and petrophysical logs has enabled the identification of three depositional sequences/cycles for the Jahrum Formation (SQ A, SQ B, SQ C) in the MD-07 well and one depositional sequence/cycle for the Asmari Formation (SQ F) in the MD-07, MD-06, and MD-02 wells of the Kuh-e-Mond Oil Field.

Considering our results within the framework of Arabian Plate sequence stratigraphy as outlined in Sharland et al. (2001), it appears that the Late Eocene Jahrum Formation in Kuh-e-Mond corresponds with the second highstand systems tract (HST) of AP10, while the Early Miocene Asmari Formation is equivalent to the second HST of the megasequence AP11.

Based on our findings, it can be concluded that the lithology, paleodepositional environmental conditions, facies, diagenetic alteration, and age of the Jahrum and Asmari successions in Coastal Fars differ from those in Interior Fars and other parts of the Zagros Basin. In Coastal Fars, these formations exhibit less thickness, lower facies diversity, and higher diagenetic alteration, especially dolomitization, compared to other parts of the Zagros Basin. Therefore, it is inferred that these formations in Coastal Fars were deposited in shallower parts of an extensive carbonate platform.

References:

Adabi M.H. Kakemem U. and Sadeghi A. 2016. Sedimentary facies, depositional environment, and sequence stratigraphy of Oligocene–Miocene shallow water carbonate from the Rig Mountain, Zagros basin (SW Iran). Carbonates and Evaporites, 31(1): 69-85.

Adabi M.H. Zohdi A. Ghabeishavi A. and Amiri-Bakhtiyar H. 2008. Applications of nummulitids and other larger benthic foraminifera in depositional environment and sequence stratigraphy: an example from the Eocene deposits in Zagros Basin, SW Iran. Facies, 54(4): 499-512.

Aqrawi A.A.M. Keramati M. Ehrenberg S.N. Pickard N. Moallemi A. Svana T. Darke G. Dickson J.A. and Oxtoby N.H. 2006. The origin of dolomite in the Asmari Formation (Oligocene-Lower Miocene), Dezful embayment, SW Iran. Journal of Petroleum Geology, 29(4): 381-402.

Aubourg C. Smith B. Eshraghi A. Lacombe O. Authemayou C. Amrouch K. and Mouthereau F. 2010. New magnetic fabric data and their comparison with palaeostress markers in the Western Fars Arc (Zagros, Iran): tectonic implications. Geological Society, London, Special Publications, 330(1): 97-120.

Babazadeh S.A. and Cluzel D. 2022. Biostratigraphy and Paleoenvironmental significance of Paleogene foraminiferal assemblages from Dashte Zari area in High Zagros, west Iran. Revista Brasileira de Paleontologia, 25(3): 189-207.

Bádenas B. and Aurell M. 2001. Proximal–distal facies relationships and sedimentary processes in a storm dominated carbonate ramp (Kimmeridgian, northwest of the Iberian Ranges, Spain). Sedimentary Geology, 139(3-4): 319-340.

Beavington-Penney S.J. Wright V.P. and Racey A. 2006. The middle Eocene Seeb Formation of Oman: an investigation of a cyclicity, stratigraphic completeness, and accumulation rates in shallow marine carbonate settings. Journal of Sedimentary Research, 76(10): 1137-1161.

Bordenave M.L. 2008. The origin of the Permo-Triassic gas accumulations in the Iranian Zagros fold belt and

contiguous offshore areas: a review of the Palaeozoic petroleum system. Journal of Petroleum Geology, 31(1):3-42.
Boukhary M. Abdelghany O. Bahr S. and Hussein-Kamel Y. 2006. Upper Eocene larger foraminifera from the Dammam Formation in the border region of United Arab Emirates and Oman. Micropaleontology, 51(6): 487-504.
Catuneanu O. 2017. Sequence stratigraphy: Guidelines for a standard methodology. In stratigraphy & timescales, 2: 1-57.
De Jong M.G.G. Smith D.G. Nio S.D. and Hardy N. 2006. Subsurface correlation of the Triassic of the UK southern Central Graben: new look at an old problem: ENRES Technical Paper Series. First Break, 24: 104-109.
Dickson J.A.D. 1965. Carbonate identification and genesis as revealed by staining. Journal of Sedimentary Research, 36(2): 491-505.
Dunham R. 1962. Classification of carbonate rocks according to depositional texture. In: Classification of Carbonate Rocks. American Assocition Petroleum Geology, 121 p.
Esrafili-Dizaji B. and Rahimpour-Bonab H. 2019. Carbonate reservoir rocks at giant oil and gas fields in SW Iran and the adjacent offshore: a review of stratigraphic occurrence and poro-perm characteristics. Journal of Petroleum Geology, 42(4): 343-370.
Fallah Bagtash R. Adabi M. Sadeghi A. and Dehyadegari E. 2020. Reservoir quality of the Jahrum carbonate succession; a case study from the Fars region of Zagros basin, SW Iran. Journal of Stratigraphy and Sedimentology Researches, 36(4): 27-58. https://doi.org/10.22108/jssr.2020.119638.1168
Fallah Bagtash R. Adabi M. Sadeghi A. and Omidpour A. 2021. A Study of microfacies and diagenetic processes of the Asmari Formation in Khesht Oil Field with emphasis on reservoir characteristic: a case study from Zagros basin, Fars, SW Iran. Journal of Stratigraphy and Sedimentology Researches, 37(3): 1-34. doi: 10.22108/jssr.2021.127061.1198
Fallah-Bagtash R. Adabi M.H. Nabawy B.S. Omidpour A. and Sadeghi A. 2022. Integrated petrophysical and microfacies analyses for a reservoir quality assessment of the Asmari Dolostone sequence in the Khesht Field, SW Iran: Journal of Asian Earth Sciences, 223: 104989.
Flügel E. 2010. Microfacies analysis of Limestones, Analysis Interpretation and Application. Springer Berlin 976 p.
Geel T. 2000. Recognition of stratigraphic sequences in carbonate platform and slope deposits: empirical models based on microfacies analysis of Palaeogene deposits in southeastern Spain. Palaeogeography, Palaeoclimatology, Palaeoecology, 155(3-4): 211-238.
Goff J.C. R.W. Jones and A.D. Horbury 1995. Cenozoic basin evolution of the northern part of the Arabian Plate and its control on hydrocarbon habitat. In, M.I. Al-Husseini (Ed.), Middle East Petroleum Geosciences Geo’94. Gulf PetroLink, Bahrain, 1: 402–412.
Gonera M. 2012. Palaeoecology of the Middle Miocene foraminifera of the Nowy Sącz Basin (Polish Outer Carpathians). Geological Quarterly, 56(1): 107-116.
Habibi T. and Ruban D.A. 2017. The Oligocene carbonate platform of the Zagros Basin, SW Iran: an assessment of highly-complex geological heritage. Journal of African Earth Sciences, 129: 675–682.
Habibi T. Pereira E. Rodrigues R. and de Oliveira L.C.V. 2024. Oligocene biostratigraphy, depositional patterns, and stable isotope values in the eastern Zagros basin: Novel insight into the signature of regional and global events. Marine and Petroleum Geology, 162: 106665.
Hag B.U. Hardenbol J. and Vail P.R. 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change: an integrated approach, Soc. Econ. Paleont. Mineral. Special Publication, 42: 71-108.
Hertig S.P. Hooks J.D. Christopher R.A. Clowser D.R. and Marshall P.R. 1995. Depositional and biostratigrahic framework of potential calci-turbidite reservoirs in the Dubai (United Arab Emirates) part of the Oman Mountain Cenozoic foreland basin. In: Al-Husseini M.I. (Ed.), Middle East Petroleum Geo94. Gulf Petro Link, Bahrain, 2: 497-504.
Heydari E. 2008. Tectonics versus eustatic control on supersequences of the Zagros Mountains of Iran. Tectonophysics, 451(1-4): 56-70.
Jafarian A. Fallah-Bagtash R. Mattern F. and Heubeck C. 2017. Reservoir quality along a homoclinal carbonate ramp deposit: The permian upper Dalan formation, South pars field, Persian Gulf Basin. Marine and Petroleum Geology, 88: 587-604.
James G.A. and Wynd J.G. 1965. Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area. American Association of Petroleum Geologists Bulletin, 49(12):2182-2245.
Kakemem U. Adabi M.H. Sadeghi A. and Kazemzadeh M.H. 2016. Biostratigraphy, paleoecology and paleoenvironmental reconstruction of the Asmari Formation in Zagros basin, southwest Iran. Arabian Journal of Geosciences, 9: 1-15.
Kakemem U. Cotton L.J. Hadavand-Khani N. Fallah-Bagtash R. Thibault N. and Anderskouv K. 2023. Litho-and biostratigraphy of the early Eocene larger benthic foraminifera-dominated carbonates of the central Tethys domain, Zagros Foreland Basin, SW Iran. Sedimentary Geology, 455: 106477.
Kamali M.R. Rezaee M.R. 2003. Burial history reconstruction and thermal modeling at Kuh-e-Mond, SW Iran. Journal of Petroleum Geology, 26(4): 415–464.
Kamran M. Frontalini F. Xi D.P. Mirza K. Jafarian A. Latif K. Ali F. Kashif M. Fawad N. Shafi M. and Wan X.Q. 2021. Larger benthic foraminiferal assemblages and their response to Middle Eocene Climate Optimum in the Kohat basin (Pakistan, eastern Tethys). Palaeoworld, 30(2): 337-355.
Khatibi Mehr M. and Adabi M.H. 2014. Microfacies and geochemical evidence for original aragonite mineralogy of a foraminifera-dominated carbonate ramp system in the late Paleocene to Middle Eocene, Alborz basin, Iran. Carbonates and Evaporites, 29: 155-175.
Mahmoodabadi R.M. 2014. Sedimentary environments and correlative sequence stratigraphy of Upper Cretaceous—Paleogene succession in Shiraz Area, Fars, SW Iran. Open Journal of Geology, 4: 1-17.
Maziqa F.H. Mahdi M.M. and Mohammed A.H. 2024. Comprehensive facies analysis and depositional environment modeling of the Eocene Dammam Formation in central to southern Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 1300, No. 1, p. 012032). IOP Publishing.
Mishra D. and Tiwari R.N. 2006. Lithofacies and

depositional dynamics of golden Oolite (Bathonian), Kachchh Mainland, Gujarat (India). Journal of Asian Earth Sciences, 26(5): 449-460.

Moallemi S.A. Adabi M.H. and Sadeghi A. 2010. Depositional history of Jahrum Formation based on distribution of benthic foraminifera and strontium isotope stratigraphy on the Bushehr area. Scientific Quarterly Journal of Geosciences, 19(74): 169-176.

Moallemi S.A. Van-Buchem F. Azzizadeh M. Daniel J.M. Callot J.P. Faure J.L. Gaumet F. Granjeon D. Javadi F. Jolapour A. Karimi Z. Letouzey J. Lotfpour M. Moretti I. Monibi S. Moradi N. Paraschovoiu E. Saffari B. Samani P. Seraj M. Shafieirad, A. Verdrene V. Ghobeishavi A. Allen T. Griffith C. Laursen G. Lopez S. Tahmasbi A.R. and Vincent B. 2008. Reservoir description of the Asmari Formation in the Dezful Embayment. Final Report, Phase, the International IOR Research Cooperation for Iranian Fields Joint Study Program, unpublished report.

Moallemi S.A. Zohdi A. and Mahboubi A. 2013. Evolution, paleoecology and sequence architecture of an Eocene carbonate ramp, southeast Zagros basin, Iran. GeoArabia, 18(4): 49-80.

Moallemi S.A. Daneshian, J. and Hosseinzadeh M. 2014. Lithostratigraphy, microfacies investigation and paleoenvironmental reconstruction of the Jahrum Formation in the west and north of the Bandar Abbass area, South Iran. Advances in Environmental Biology, 8(4): 963-974.

Mohseni H. Hassanvand V. and Homaie M. 2016. Microfacies analysis, depositional environment and diagenesis of the Asmari–Jahrum reservoir in Gulkhari oil field, Zagros basin, SW Iran. Arabian Journal of Geosciences 9: 1-21.

Nadjafi M. Mahboubi A. Moussavi-Harami R. and Mirzaee R. 2004. Depositional history and sequence stratigraphy of outcropping Tertiary carbonates in the Jahrum and Asmari formations, Shiraz area (SW Iran). Journal of Petroleum Geology, 27(2): 179-190.

Nio S. Djin Brouwer J. Smith D.G. De Jong M. and Böhm A. 2005. Spectral trend attribute analysis: applications in the stratigraphic analysis of wireline logs. First Break, 23(4): 71-75.

Omidpour A. and Fallah-Bagtash R. 2022. Investigation of sedimentary facies and geochemical parameters of the Asmari Formation (Oligocene-Miocene) in the Shadegan Oil Field, Dezful Embayment, SW Iran. Researches in Earth Sciences, 13(2): 162-188.

Omidpour A. Mahboubi A. and Fallah-Bagtash R. 2023. The role of relative sea-level fluctuations on dolomitization of carbonate reservoirs Case study: Asmari Formation. Journal of Stratigraphy and Sedimentology Researches, 39(2): 59-80. https://doi.org/10.22108/jssr.2023.138904.1268

Omidpour A. Mahboubi A. Moussavi-Harami R. and Rahimpour-Bonab H. 2022. Effects of dolomitization on porosity–Permeability distribution in depositional sequences and its effects on reservoir quality, a case from Asmari Formation, SW Iran. Journal of Petroleum Science and Engineering, 208: 109348.

Omidpour A. Moussavi-Harami R. Mahboubi A. and Rahimpour-Bonab H. 2021. Application of stable isotopes, trace elements and spectral gamma-ray log in resolving high-frequency stratigraphic sequences of a mixed carbonate-siliciclastic reservoirs. Marine and Petroleum Geology, 125: 104854.

Parvaneh Nejad Shirazi M.L. Yazdandoust L. and Moradi Z. 2014. Microfacies and sedimentary environment of the Asmari Formation in Dashtak Anticline (north-west of Kazerun). New Findings in Applied Geology, 8(16): 1-14.

Philip J. 2003. Peri-Tethyan neritic carbonate areas: Distribution through time and driving factors. Palaeogeography, Palaeoclimatology, Palaeoecology, 196: 19–37.

Sadeghi R. Khajoie M.H. and Jokar M. and 2015. Lithostratigraphy and sedimentary environment of the Jahrum Formation in the Jahrum and Tudej Anticlines. Journal of Petroleum Geology, 4 (8): 78-103.

Sadooni F.N. and Alsharhan A.S. 2019. Regional stratigraphy, facies distribution, and hydrocarbons potential of the Oligocene strata across the Arabian Plate and Western Iran. Carbonates and Evaporites, 34(4): 1757-1770.

Sepehr M. and Cosgrove J.W. 2004. Structural framework of the Zagros fold–thrust belt, Iran. Marine and Petroleum Geology, 21(7): 829-843.

Shariatinia Z. Haghighi M. Feiznia S. Alizai A.H. and Levresse G. 2013. Hydrocarbon migration in the Zagros Basin, offshore Iran, for understanding the fluid flow in the Oligocene–Miocene carbonate reservoirs. Journal of Russian Geology and Geophysics, 54(1): 64-81.

Sharland P.R. Casey D.M. Davies R.B. Simmons M.D. and Sutcliffe O.E. 2001. Arabian plate sequence stratigraphy. GeoArabia, 2: 371.

Soltani B. Rahimpour-Bonab H. Ranjbaran M. 2013. Regional stratigraphic correlation and comparison of the Oligo-Miocene deposits in Dezful (SW Iran) and Kirkuk (N and NE Iraq) embayments. J. Zankoy Sulaimani Part A 15: 77–93.

Taheri A. Vaziri-Moghaddam H. and Seyrafian A. 2008. Relationships between foraminiferal assemblages and depositional sequences in Jahrum Formation, Ardal area (Zagros Basin, SW Iran). Historical Biology, 20(3): 191-201.

Thomas A.N. 1948. The Asmari limestone of southwest Iran. National Iranian Oil Company, Report, 706.

Thomas A.N. 1952. Facies variations in the Asmari Limestone. 18th Int. Geol. Congr. (Gt. Britain, 1948). Proc., part, 10: 74-82.

Vail P.R. Mitchum R.M. and Samuel Thompson Jr. 1977. Seismic stratigraphy and global changes of sea level: Part 3. Relative changes of sea level from Coastal Onlap: section 2. Application of seismic reflection Configuration to Stratigraphic Interpretation, 63-81.

Vaziri-Moghaddam H. Seyrafian A. Taheri A. and Motiei H. 2010. Oligocene-Miocene ramp system (Asmari Formation) in the NW of the Zagros basin, Iran: Microfacies, paleoenvironment and depositional sequence. Journal of Revista Mexicana de Ciencias Geológicas, 27(1): 56-71.

Warren J.K. 2006. Evaporites: sediments, resources and hydrocarbons. Springer Science & Business Media, 1034 p.

Wilson J. 1975. Carbonate Facies in Geological History. Springer, Berlin. 471 p.

Zamagni J. Mutti M. and Košir A. 2008. Evolution of shallow benthic communities during the Late Paleocene–Earliest Eocene transition in the Northern Tethys (SW Slovenia). Facies, 54: 25-43.

Ziegler M. 2001. Late Permian to Holocene paleofacies evolution of the Arabian plate and its hydrocarbon occurrences. GeoArabia, 6(3): 445–504.

Zohdi A. Mousavi-Harami R. Moallemi S.A. Mahboubi A. and Immenhauser A. 2013. Evolution, paleoecology and sequence architecture of an Eocene carbonate ramp, southeast Zagros Basin, Iran. GeoArabia, 18(4): 49-80.

Zulnoorian H. Mirbeik Sabzevari K. Asgari-Pirbalouti B. Shahrokhi S.V. and Baharvand S. 2023. Biostratigraphy of the late Eocene-Miocene (Jahrum & Asmari formations) in the west and southeast of the Shahr-e Kord (Central Zagros). Advanced Applied Geology, 13(3): 641-660.

https://doi.org/10.22108/jssr.2024.140390.1276