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Paleoecology of Early to Middle Miocene Deposits (Guri Member) and Sedimentary Environment, SE Zagros Zone, Roydar, Iran

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Abstract

This research focusses on the facies distribution, paleoenvironment and paleoecology of the foraminifera of the Guri Member in the northern Bandar Abbas Hinterland located in the Roydar area of southern Iran. The Guri Member is 570 meters thick and composed of limestone, argillaceous limestone and marl. The distribution of the foraminifera in the study area indicates the existence of three biozones ranging from early to middle Miocene in age. Based on petrographical studies, depositional textures and fauna, eight microfacies were identified. The paleoecology, lithology and environmental interpretations were characterized by an open marine environment with an upward, gradually shallowing trend. Additionally, three distinct depositional settings were identified: tidal flat, inner ramp and middle ramp. Microfacies (MF) 1, representing a distal middle ramp setting, was characterized by the occurrence of hyaline, benthic and planktonic foraminifera. MF2 and MF3 were characterized by the occurrence of Miogypsina, Elphidium and red algae. They represent a deeper low energy in the wave base of a middle ramp setting. MF4 was characterized by an abundance of rotaliids and red algae representing a proximal middle ramp environment. MF5 and MF6 were identified by the occurrence of large and small porcelaneous benthic foraminifera representing a shallow-water inner ramp setting. MF7 and MF8 were characterized by the occurrence of gastropods and bivalves in a shallow-water setting of tidal flats influenced by both wave and tidal processes. Palaeolatitudinal reconstructions based on skeletal grains suggest that the Guri Member existed in tropical waters within a carbonate ramp.

Keywords: *microfacies, paleoenvironment, carbonate ramp, Guri Member, Zagros Zone and Bandar Abbas Hinterland.*

1. Introduction

The Mishan Formation is composed of two rock units, a thick to massive rock unit made up of hard limestone called the Guri Member and a very thick unnamed unit of green/grey marl. The Guri Member, formerly called the Guri Formation or Operculina limestone, makes up the lower portion of the Mishan Formation [1]. The section of this carbonate member located in northwestern Lar (Fars Province) is 112.5 m thick and consists of hard, massive, cream, fossiliferous limestone with thin-bedded intercalations of marls [2 and 3]. The studied area is geologically located in the Bandar Abbas Hinterland in the southeastern most portion of the Zagros Basin (Fig. 1). The Mishan Formation is present in most of the Zagros Basin [3] (Fig. 2) but is well developed in Hormozgan Province and the Bandar Abbas Hinterland; the eastern border is limited by the Minab Fault [2].

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The Guri Member gradationally overlies the Gachsaran Formation and contact with the overlying marly, unnamed unit is gradational. The Guri Member in the studied area consists of 570 m of thick to medium-bedded limestone and medium-bedded argillaceous limestone with thin-bedded intercalated green marl. One stratigraphic section was chosen for this article with the following main objectives in mind: description of the facies and their distribution on the early to middle Miocene carbonate platform and interpretation of the paleoenvironmental features based on the assemblages of microfaunas.

2. Geological Setting

The Zagros Basin is defined by a 7–14 km thick succession of deposits over a region along the north–northeastern edge of the Arabian plate. This basin was part of the stable Gowndwana supercontinent in the Paleozoic Era, a passive margin in the Mesozoic, and became a site of convergent orogeny in the Cenozoic [4].

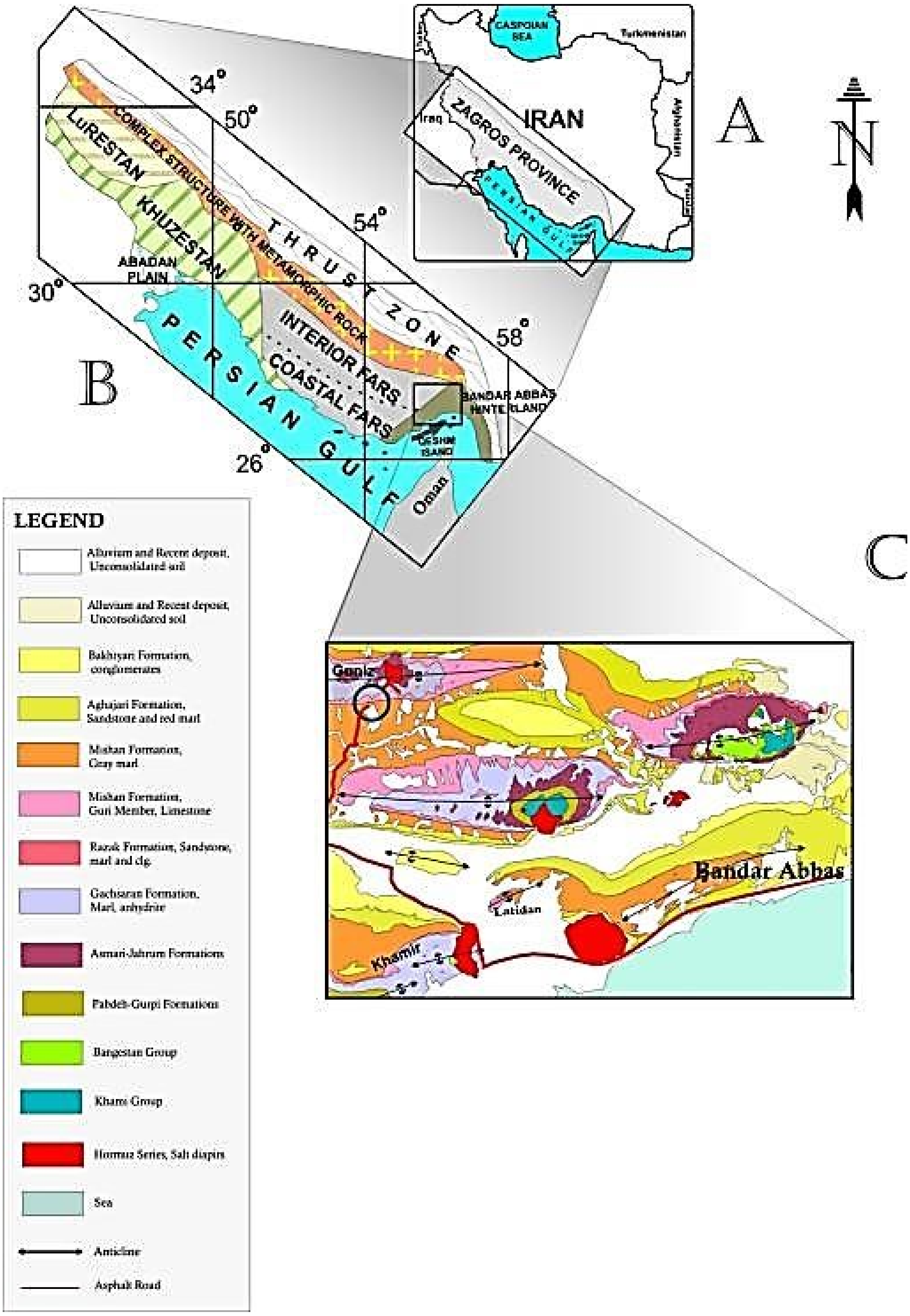

Fig 1: (A) General map of Iran showing the Zagros Province (B) Structural of Zagros [2] (C) Location map of the studied section modified after National Iranian Oil Company.

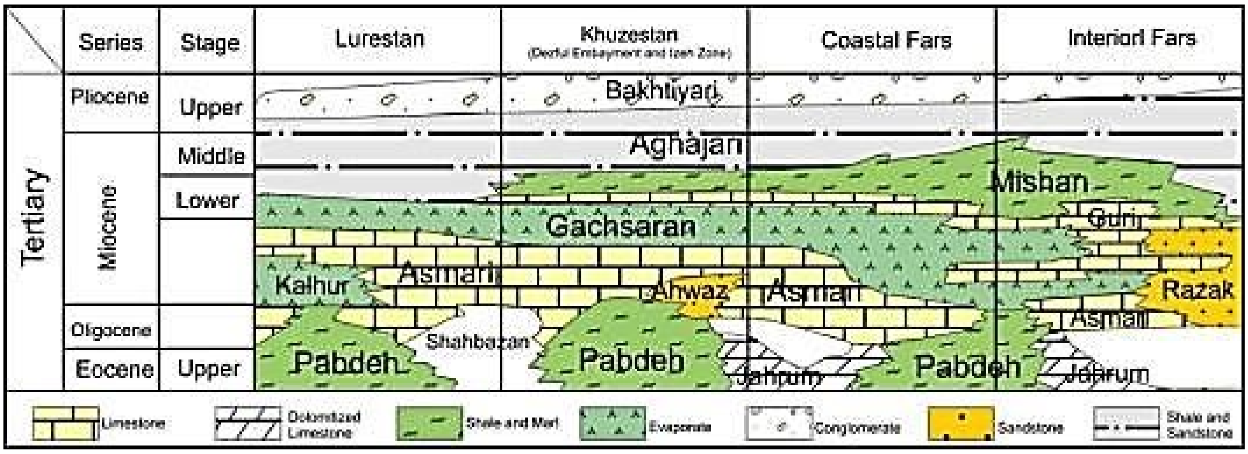

Fig 2: Cenozoic stratigraphic correlation chart of the Iranian sector of the Zagros Basin, adopted from [1].

The Zagros Fold-and-Thrust Belt of Iran is the result of Alpine orogenic events, which occurred in the Alp–Himalayan mountain range [5 and 6]. It extends in a NW–SE direction from eastern Turkey to the Strait of Hormoz in southern Iran. The tectonic activity of this area was entirely due to the convergence of the Arabian and Eurasian continents.
The maximum thickness of the Guri Member is located in the Bandar Abbas Hinterland [2]. On the basis of lateral facies variations, the Iranian Zagros Fold-Thrust Belt is divided into different tectonostratigraphic domains that, from SE to NW, are known as the Fars Province (eastern Zagros), Khuzestan Province (central Zagros) and Lurestan Province (western Zagros) respectively [3]. Hormozgan Province is located in southern Iran and is part of the Zagros Folded Belt. This region, called the "Bandar Abbas Hinterland" by Motiei [3] (Fig. 1), is accompanied by NW-SE, W-E and N-S trending simple anticlines and synclines of very great thickness in the Fars Group deposits (Gachsaran, Mishan, Aghajari and Bakhtiari formations) and contains 118 visible salt plugs.

3. Material and Methods

The study area is located in the Guniz anticline of the northwestern Bandar Abbas area in southern Iran. This research involves one stratigraphic section of the Guri Member. The section was measured at 27° 29' 16" N and 55° 24' 44" E. (Fig. 1). The lithology and microfacies types were classified and described according to Dunham [7] and Embry and Klovan [8]. A total of 130 thin cutting were examined under a microscope for biostratigraphy and facies studies. Microfacies were determined for each paleoenvironment according to texture, grain type, distribution and interpretation of microfossils (Fig 3).

4. Biostratigraphy

The biostratigraphic criteria of the Guri Member were established by Wynd [9] and reviewed by Adams and Bourgeois [10] in unpublished reports only. Age determinations in the study area are based on the biozonation of Wynd [9] and Adams and Bourgeois [10]. Three foraminiferal biozones were recognized and are discussed in stratigraphic order as follows:

4-1. Biozone I: *Elphidium*sp. - *Miogypsina* Assemblage Subzone

Age: Aquitanian
This biozone corresponds to the *Elphidium*sp. - *Miogypsina* Assemblage Subzone (2a) of Adams and Bourgeois [10]. The age of this assemblage is considered to be early Miocene (Aquitanian). The most diagnostic species include:

*Neorotaliaviennoti, Ammonia beccarii, Ammonia stachi, Discorbis*sp., *Glomospira*sp., *Neorotalia*sp., *Quinqueloculina* sp., *Reussella* sp., *Dendritinarangi*, *Pyrgo* sp., *Archaiaskirkukensis, Spiroloculina* sp., *Spirolina*sp., *Amphistegina*sp., *Heterallina*sp., *Triloculinatrigonula, Archaias*sp., *Borelis*sp., *Textularia*sp., *Sphaeroypsina globules, Globigerina* sp. Non-foraminiferal include: *Ditrupa*sp., *Tubucellaria* sp., *Memberanipora* sp. and *Onychosella* sp.

4-2. Biozone II: *Borelismelocurdica* Taxon Range Zone

Age: Burdigalian-Langhian
This biozone corresponds to the *Borelismelocurdica* total range zone (61 and 62) of Wynd [9] This biostratigraphic interval is characterized by the total range of the *Borelismelocurdica* between its FOD and LOD.

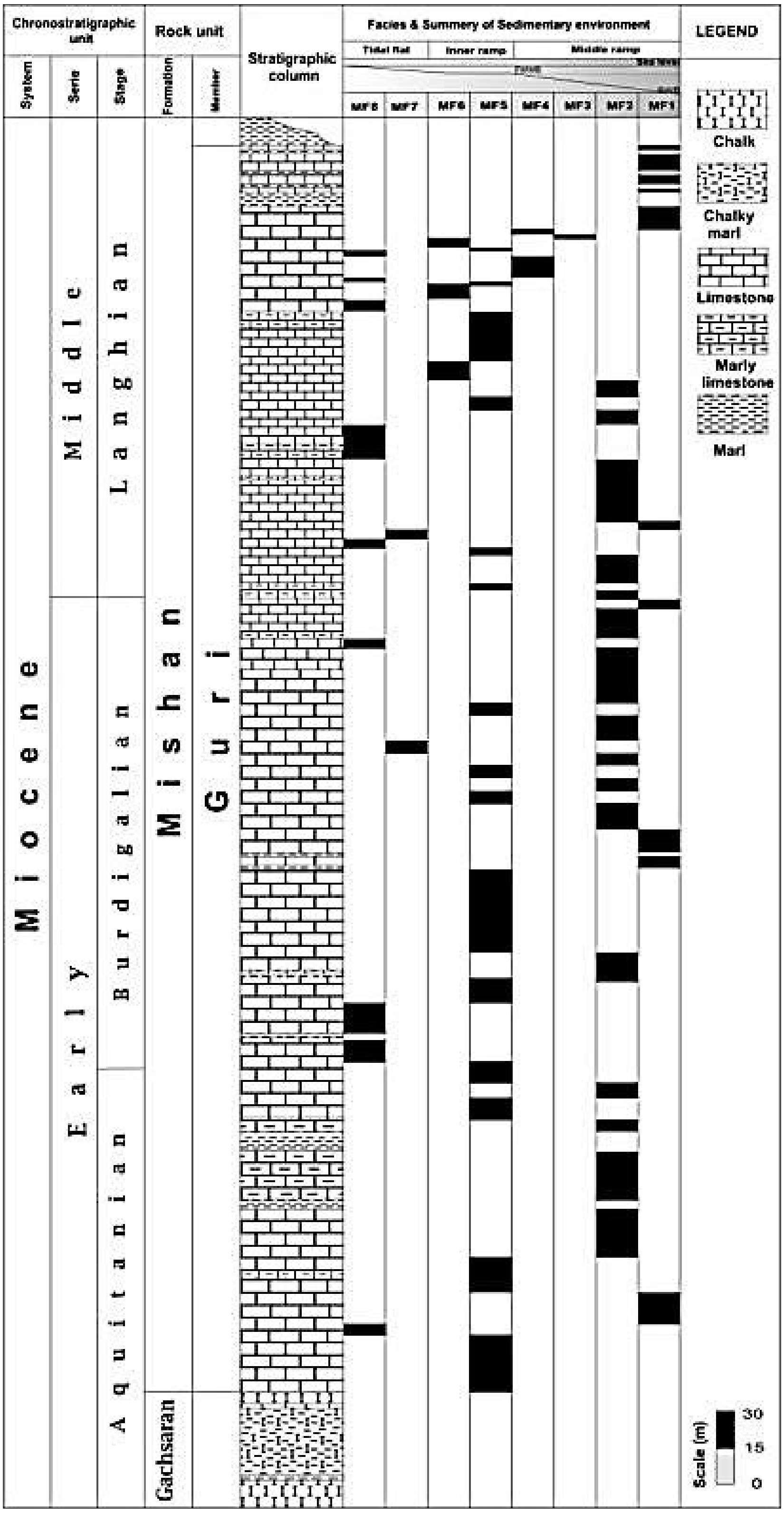

Fig 3: Lithostratigraphy column and microfacies of the Guri Member in NW Hormozgan (Roydar section)

The age of this zone is considered to be Burdigalian-Langhian. The most important species associated with this biozone are:

*Neorotaliaviennoti, Ammonia beccarii, Ammonia stachi, Discorbis*sp.*, Glomospira*sp.*, Neorotalia*sp.*, Quinqueloculina* sp., *Reussella* sp., *Dendritinarangi*, *Miogypsina*sp.*, Pyrgo* sp., *Archaiaskirkukensis, Spiroloculina* sp.*, Spirolina*sp., *Elphidium*sp.14*, Amphistegina*sp., *Heterallina*sp.*, Triloculinatrigonula, Archaias*sp.*, Borelis*sp., *Textularia*sp.*, Sphaerogypsina globules, Meandropsinaanahensis, Schlumbergerina* sp., *Borelishaueri, Peneroplis*cf. *evolutus, Praehapydionina delicate, Spirolina*cf. *cylandrica*, *Miolepidocyclina* sp.*, Peneroplisfarsenensis, Archaiashensoni, Bigenerina*sp.*, Triloculinatricarinata, Globorotalia*sp.*, Orbulina sp., Globigerinoides*sp.*, Globigerinoides*cf. *subquadratus*
Non-foraminiferal are as follows:
*Ditrupa*sp., *Subterraniphyllumtomasi, Lithothamnium*sp.,*Tubucellaria* sp., *Memberanipora* sp., *Onychosella* sp. and corals.

4-3. Biozone III: *Globorotalia* (*fohesella*) *peripheroronda* Interval Zone

Age: Middle Miocene (Langhian)
This biozone is equivalent to the *Globorotalia* (*fohesella*) *peripheroronda* Interval Zone of Boli (1957). This interval is characterized by the lowest occurrence of *Orbulina and Globorotalia (fohesella) peripheroronda.* Its age is considered to be Langhian. The associated fauna are:

*Neorotaliaviennoti, Ammonia beccarii, Ammonia stachi, Discorbis*sp.*, Glomospira*sp.*, Neorotalia*sp.*, Quinqueloculina* sp., *Reussella* sp., *Dendritinarangi*, *Miogypsina*sp.*, Pyrgo* sp., *Archaiaskirkukensis, Spiroloculina* sp.*, Spirolina*sp., *Amphistegina*sp., *Heterallina*sp.*, Elphidium*sp.14*, Triloculinatrigonula, Borelis*sp., *Textularia*sp.*, Borelismelocurdica, Meandropsinaanahensis, Schlumbergerina* sp., *Borelishaueri, Miolepidocyclina* sp.*, Praehapydionina delicate, Peneroplisfarsenensis, Archaiashensoni, Bigenerina*sp.*, Triloculinatricarinata, Operculinacomplanata, Miogypsinoides*sp.*, Elphidiummacellum, Spiroloculinacommunis, Quinquloculina*cf. *vulgaris, Amphistegina*cf. *lessoni, Asterorotaliamultispinosa, Nodosaria*sp.*, Textulariapala, Bigenerinanodosaria, Globigerinoides*cf. *trilobus*, *Globigerinoides*cf. *subquadratus.*
Non-foraminifera include:
*Ditrupa*sp., *Subterraniphyllumtomasi, Lithothamnium*sp., *Lithothamnium*cf. *ramosissimam, Lithophyllum* sp.,*Tubucellaria* sp., *Memberanipora* sp., *Onychosella* sp., *Cidaris*sp.

5. Microfacies Analysis

Facies analysis of the Guri Member in the study areas defined eight facies types, characterized by carbonate platform development. Each of the microfacies exhibit typical skeletal and non-skeletal components and textures. These facies are related to the three depositional settings (tidal flat, inner ramp and middle ramp) of a carbonate platform (Fig. 5). The general environmental interpretations of the microfacies are discussed in the following paragraphs.

MF1*. Planktonic, Miogypsina, Operculinapackstone* (Fig. 4)
The main feature of this facies is the abundance of large and flat *Operculina* and *Miogypsina*. Other components include *Globigerina* sp. and *Globorotalia*sp. The matrix is composed of fine-grained micrite with a packstone texture [11].
Interpretation
The benthic fauna and abundance of different planktonic foraminifera suggest that this facies was deposited in calm, low energy hydrodynamic and deep, normal saline water indicating a distal middle ramp and the beginning of an outer ramp setting [12, 13, 14,15 and 16].

MF2*. Elphidium, Miogypsinawackestone-packstone* (Fig. 4)
This facies is dominated by *Miogypsina* and *Elphidium* with subordinate components such as bryozoan. This facies has a fine-grained matrix that is composed of micrite with a wackestone texture. Additional components that change the facies texture to packstone include: *Neorotaliaviennotti, Sphaerogypsinaglobulus, Dendritinarangi, Globigerinoides*sp [17].
Interpretation
The simultaneous occurrence of *Elphidium* with *Miogypsina* and *Globigerinoides* indicates a middle ramp setting [18 and 19].

MF3*. Red algae packstone* (Fig. 4)
This microfacies is predominantly composed of red alga (*Lithotamnium* and *Lithophyllum*). Other components such as *Ditrupa*sp. are rare. The depositional texture is characteristic of packstone.
Interpretation
The absence of foraminifera and abundant red algae suggests a middle ramp environment [12].

MF4*. Bioclast, Rotaliids, red algae wackestone-packstone* (Fig. 4)
This facies is characterized by the dominant presence of red algae, *Neorotalia* and *Ammonia*. Other bioclast are rare but include bryozoans and fossil debris. The texture is that of wackestone-packstone.

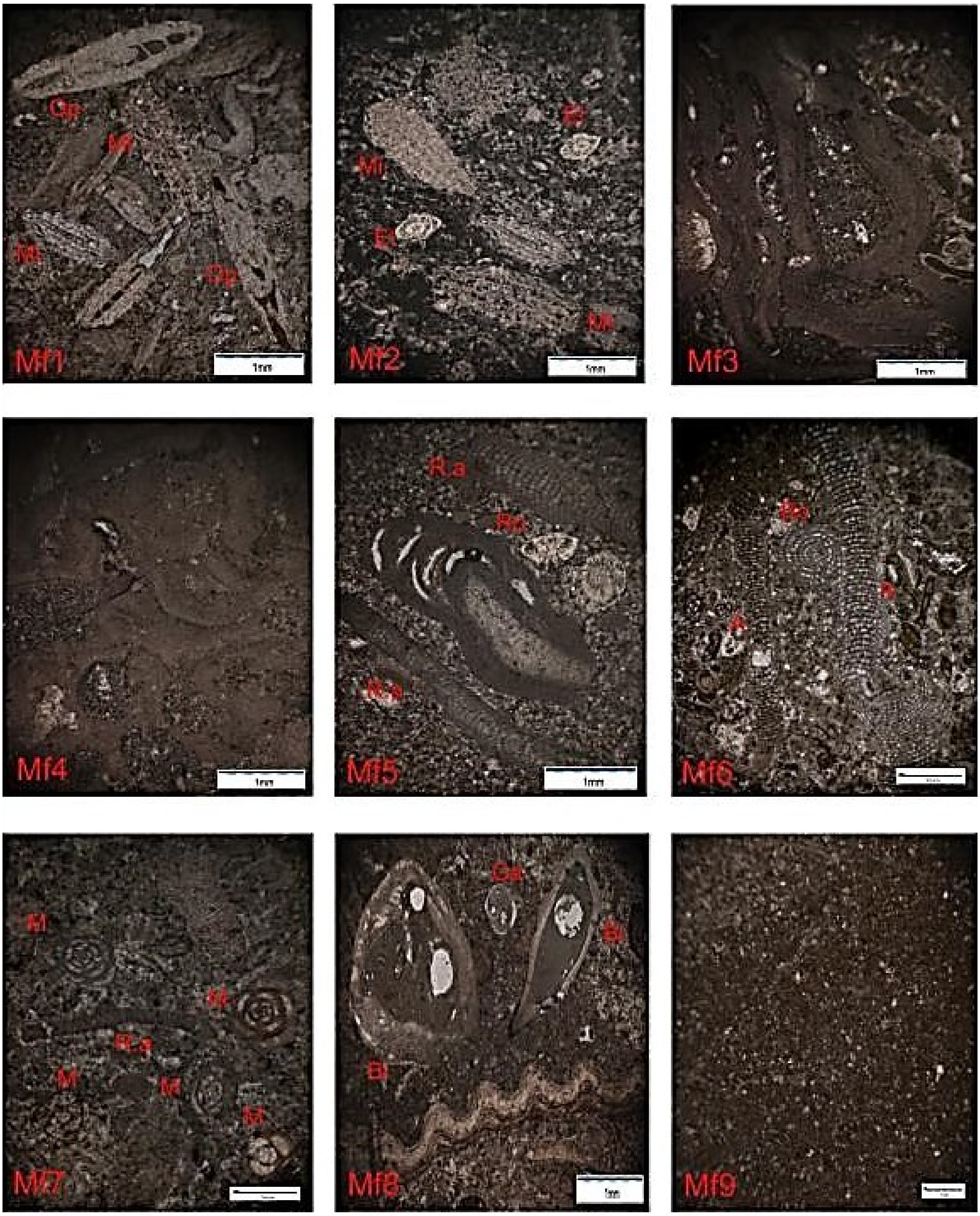

Fig 4: Guri Member microfacies types MF1: Planktonic, Miogypsina, Operculinapackstone, MF2: Elphidium, Miogypsinawackestone-packstone, MF3: Red algae packstone, MF4: Bioclast, Rotalid, red algae wackestone-packstone, MF5: Borelis, Archaiaswackestone-packstone, MF6: Miliolidswackestone, MF7: Bioclastwackestone. MF8: Mudstone - (Mi: Miogypsina, Op: Operculina, El: Elphidium, R.a: Red Algae, Ro: Rotalia Bo: Borelis, A: Archaias, M: Miliolid, Ga: Gastropod, Bi: Bivalve)

Interpretation

This depositional environment is the upper part of a carbonate slope. The presence of *Neorotalia* and *red algae* identifies this microfacies as a proximal middle ramp.

***MF5**. Borelis, Archaiaswackestone-packstone* (Fig. 4)

The main elements of this microfacies include *Archiaskirkukensis*, *Borelismelocurdica* and *Archaia sp.* Other association biota include miliolids (*Spiroloculina*sp., *Quiquloculina* sp. and *Pyrgo* sp.)

and *Dendritinarangi*. Porcelaineous imperforate foraminifera such as *Archias* and *Borelis* generally live in photic zones [20].

Interpretation

Tests showing the occurrence of a large number of porcelaneous imperforate foraminiferal could support the existence of a slightly hyper-saline depositional environment [21]. These deposits include different textures ranging from wackestone to packstone. Some porcelaneous imperforate foraminiferal (*Archaias*, *Borelis* and Miliolids) live in recent tropical and subtropical shallow water environments. Textural characteristics and prolific porcelaneous foraminifera, suggest a medium energy portion of an open lagoon in an inner ramp environment [12, 15, 22, 23 and 24].

MF6. *Miliolidswackestone* (Fig. 4)

The main elements of this microfacies include miliolids (*Triloculinatrigonula*, *Quiquloculina* sp., *Schlumbergerina* sp., *Spiroloculina*sp., *Pyrgo* sp.) and red algae (*Subterraniphyllumthomasi*). This facies is characterized by the dominant presence of miliolids with a sparite cement and wackestone texture.

Interpretation

The occurrence of miliolids with *Subterraniphyllumthomasi* indicates that sedimentation took place in a low to medium energy open lagoon of an inner ramp environment.

MF7. *Bioclastwackestone* (Fig. 4)

The main skeletal components of this facies are gastropods and bivalves. Other bioclasts found in some samples include bryozoan debris. The main characteristic of this microfacies is the absence of foraminifera and the presence of microfauna debris and a wackestone texture.

Interpretation

Based on the low diversity of skeletal fauna and the type of bioclasts, this facies was deposited in a high-energy, near-coast environment indicative of a tidal flat [15].

MF8. *Mudstone* (Fig. 4)

This microfacies is composed of dense lime-mudstone. The facies contains particularly poor fauna. A small number of microfauna such as miliolids, *Ammonia beccari* and *Borelismelocurdica* were also present in some samples. The poor fauna indicate sensitive conditions in restricted water circulation.

Interpretation

This facies contains sparse non-digenetic fauna. Based on the above explanation this microfacies belongs to a near-coast, tidal flat environment.

6. Paleoecology

Euphotic conditions prevailed in the Miocene and carbonate production led to the decline of the foraminifers [25]. Larger perforate forms are represented by *Operculina, Elphidium* and *Miogypsina*). Perforate foraminifera that live in shallow waters are characterized by hyaline walls. They protect themselves from ultra violet light by producing very thick, lamellar test walls to prevent photo inhibition of symbiotic algae within the test in bright sunlight. These large forms are the most important indicators for paleo-environmental model reconstructions in warm, shallow marine environments [18 and 26]. The presence of these large, flat forms (*Operculina* and *Miogypsina*) in the Guri Member of the Mishan Formation in comparison with analogues in the modern platform led to the interpretation of these sediments as being photic zone deposits [27, 28, 29, 30, 31 and 32].

Because most phototrophic carbonate producers thrive in shallow marine environments [25] , red algae and bryozoan communities became dominant especially through the early to late Miocene (Aquitanian to Tortonian) [33]. Red algae and large benthic foraminifera (*Operculina*, *Archaias*, *Borelos* and *Elphidium*) are the most significant and dominant biota in the Guri Member in the study area. Other components such as bryozoan and red algae are present within the matrix in addition to echinoderm test being observed in the field study. The distribution of larger foraminifera and red algae is particularly dependent upon the salinity, depth, light, temperature, climate, nutrients, effect of hydrodynamic energy and flows substrate on the biostrate and dispersion of taxa [34 and 35]. Small benthonic foraminifera are common locally and include porcelaneous (miliolids) and perforated (rotaliids) forms. Rotaliids are dominated by *Neorotaliaviennoti* and *Ammoniabeccarii*. Larger foraminifera, represented by porcelaneous imperforate tests such as *Archaias* and *Borelis,* may support the existence of a photic zone in tropical carbonate platforms and slightly hypersaline water [12, 15 and 23]. Flatter tests and thinner walls indicate an increase in water depth and decreased light levels at greater depths or poor water transparency in shallow waters [36]. Some biogenic components such as miliolids indicate stress conditions within a restricted environment such as a lagoon.

A miliolid dominate environment in a benthic foraminifer assemblage reflects decreased circulation and reduced oxygen content or euryhaline conditions. Miliolids are found in a variety of very shallow, hyposaline to hypersaline environments and are also common in sand shoal environments of normal salinity [37 and 38]. They are generally evidence of a restricted lagoon environment [11]. Other important components are planktonic forms. The presence of planktonic (*Orbulina*, *Globigerina, Globigerinoides* and *Globorotalia*) is indicative of the deep, quiet waters of an open marine environment [26].

7. Depositional Environment

Open lagoon shallow subtidal environments are characterized by mixed open marine bioclasts including red algae, echinoids and bryozoans as well as protected environment bioclasts such as miliolids. The presence of imperforate foraminifers including *Archaias*, *Borelis* and miliolids, indicates a low-energy, upper photic, shallow lagoonal depositional environment of inner ramp. A large number of porcellaneous imperforates foraminifera indicates the presence of a hypersaline marine environment [11 and 18]. Large porcelaneous types such as *Archaias* and *Borelis* are present in MF5. The occurrence of *Archaias* and *Borelis* is typical of recent tropical and subtropical shallow water environments [39]. Furthermore, these large porcelaneous foraminiferas are also common in Mesozoic and Cenozoic neritic sediments [33]. The change in larger foraminiferal fauna from porcelaneous imperforated to hyaline perforated forms points to decreased water transparency [40]. The diversity of skeletal components indicates a shallow subtidal environment under optimal conditions with regards to the salinity and water circulation. The faunal association suggests that the depositional environment was situated in the mesophotic to oligophotic zones [41 and 42].

Carbonate ramp environments are characterized by: (1) tidal flats, between mean high tides (MHT) to mean low tides (MLT), (2) inner ramp, between the upper shore face and fair weather wave base (FWWB), (3) middle ramp, between fair weather wave base and storm-wave base (SWB), and (4) outer ramp, below normal storm-wave base down to the basin plain [43 and 44] (Fig. 5). Interpretations of this environment are represented by eight microfacies types (Fig. 3). MF1 shows a distal middle ramp while MF2-MF4 show a middle ramp setting. Microfacies 2 through 4 are subjected to a deeper fair water wave base between distal to proximal middle ramps respectively. MF5 and MF6 were deposited in a medium energy, shallow-water setting of an inner ramp influenced by wave and tide processes. MF7 and MF8 were deposited in a tidal flat off the coast. More common small benthic foraminifera (*Neorotalia* and *Ammonia*) and red algae are dominate in the lower photic zone. Additionally, the red algae associated with larger foraminifers represent the middle ramp and oligophotic to mesophotic zone [33, 41, 42, 45 and 46].

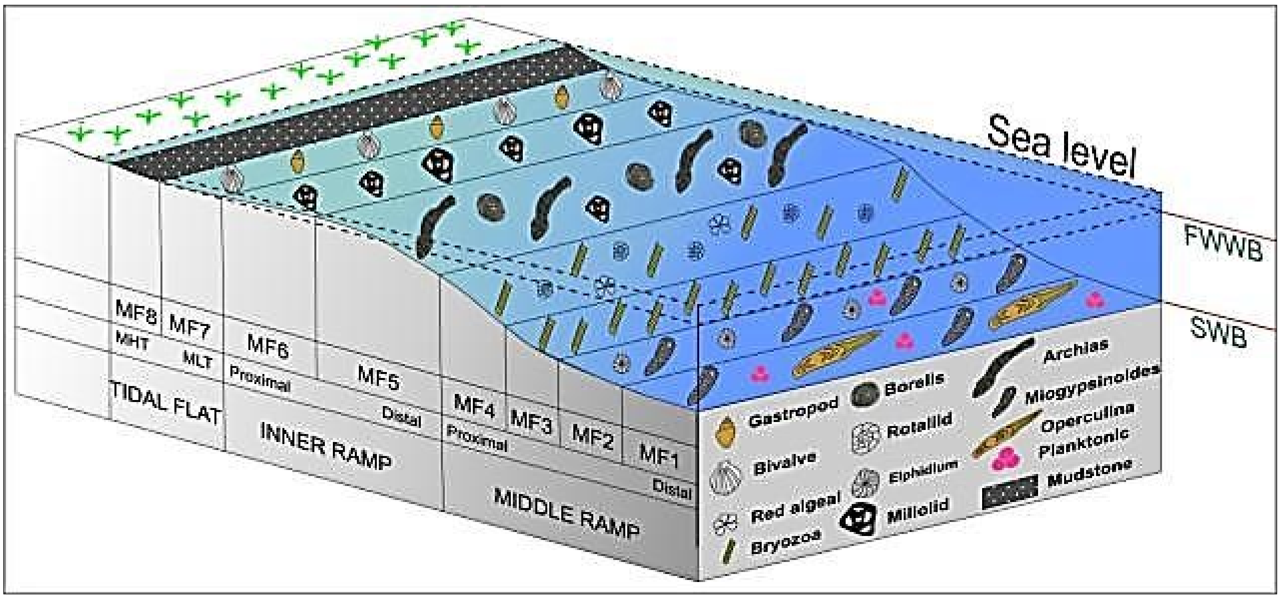

Fig 5: Depositional model for the carbonate platform of the Guri Member southeastern portion of Zagros Basin, NW Hormozgan Province. Interpretation adopted from [41].

8. Conclusions

The early to middle Miocene (Guri Member) of the Mishan Formation is a thick sequence of shallow water carbonate in the Zagros Basin, especially the Bandar Abbas Hinterland. The occurrence of large foraminifera (*Operculina*, *Miogypsina, Archaias*, *Borelis*), red algae, bryozoans and fragments of mollusks indicates high nutrient stability in oligo to mezothrophic and tropical conditions, existing during the deposition of the Guri Member. Based on the occurrence of these fossils, three biozones (*Elphidium*sp. -*Miogypsina* Assemblage Subzone, *Borelismelocurdica* Total Range Zone and *Globorotalia* (*fohsella*) *prepheroronda* Interval Zone) were recognized and the Guri Member identified as being Aquitanian to Langhian in age. Based on the components and texture, eight microfacies types were identified and grouped into three depositional environments that correspond to the tidal flat, inner and middle ramp. Microfacies 1-4 were subjected to an open marine environment of a middle ramp, microfacies 5 and 6 were part of an inner ramp/platform environment and microfacies 7 and 8 were part of a tidal flat off the coast. These assemblages of the Guri Member suggest that carbonate sedimentation took place in tropical waters and oligotrophic to slightly mesotrophic conditions.

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