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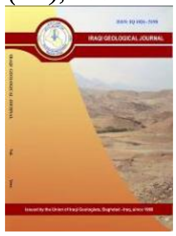

Combined Ostracoda and Foraminiferal Biozonation with Environment of Fatha Formation (Middle Miocene) In Different Oilfields, Southern Iraq

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Abstract

The Fatha Formation is a significant stratigraphic unit that was deposited during the Miocene; its sediments covered the basin from the north to the south of Iraq. Six oil wells within four oilfields were chosen for the current study. Both types of samples (core and cutting) were prepared to extract the existing fossils. Forty-two foraminifera species belonging to twenty-one genera and forty ostracods species belonging to thirty genera were identified. On the basis of the biostratigraphic distribution of the foraminifera and ostracoda species, one biozone for foraminifera was plotted which is *Elphidium craticulatum* taxon range zone, also one biozone of ostracoda was determined which is *Schneiderella unispinata* Assemblage zone. The age of Fatha Formation is Middle Miocene depending on the index fossils of the ostracods. All genera recorded in the study area belong to benthic foraminifera except one genus (*Globigerina quinquelob*) belongs to the planktonic foraminifera. The environment of the Fatha Formation in the southern basin is slightly different from the northern basin, but the main environment is still a lagoon but it is accompanied by several other environments such as shallow water, tidal and subtidal. The lagoon was partially closed, and it was affected by marine water, especially in the lower part of the studied formation.

Keywords: Fatha Formation; Foraminifera; Ostracoda; Miocene; Southern Iraq

1. Introduction

The Fatha Formation is an important stratigraphic unit in the Middle East: it is the caprock to numerous oil reservoirs in Iraq and Iran (Tuker, 1999). Busk and Mayo (1918) are the first to describe the studied formation in Iran, exactly in the province of Fars with the name Lower Fars (Van Bellen et al., 1959). According to Jassim et al. (1984) the Fatha Formation was proposed to replace the old name in Iraq, and select of Fatah area (Hemrin and Makhul anticlines) as a type locality for it.

The Middle Miocene of Fatha Formation is one of the most widespread formations in Iraq, extending from North to South of Iraq (Al-Juboury et al., 2001; Jassim and Goff, 2006). It is characterized by rhythmic nature (Al-Juboury and McCann, 2008). Each rhythm comprises two to five lithologies namely, greenish-grey marl, limestone, gypsum (and/or anhydrite), halite, and reddish-brown mudstone (with occasional sandstone) (Tamar-Agha et al., 2015). It has uncommercial criteria for petroleum and gas accumulation in some oilfields in central Iraq (Al-Jubury and McCann, 2008). Also, the current formation considers a cup-rocks for many important oilfields in Iraq. However, in northern Iraq, it includes a significant amount of Sulphur (Aqrawi et al., 1989). This study considered is the first detailed paleontological study in the South of Iraq for Fatha Formation, most of the previous studies

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focused on central and Northern Iraq, especially in the outcrops, but in Basrah oilfields, the studies are rare. The important previous studies are Abdol Rassul et al. (2001), Al-Asadi, (2002), Hawramy, (2013), Hawramy and Ali (2018), Al-Hadithi and Aziz, (2019) and Khalaf and Kharruffa,(2020). They are intensive Ostracoda studies in North of Iraq, while rare studies specifically related to Foraminifera. Mahdi, (2007) and Al-Abbasi et al., (2011) studied the bivalve in Northern Iraq. In addition to several essential stratigraphical studies such as Aqrawi et al. 1989, Al-Jubouri and McCann, 2008, Tamar-Agha et al., 2015 and Sissakian et al., 2016., etc. This study mainly aims to identify the important fossils groups (Foraminifera and Ostracods) and then divided them into local biozone and correlated this biozone with other studies. Also, to determine the environment of the formation, this study is first at Southern Iraq that used of core samples, in addition to identifying new species in the formation.

2. Materials and Methods

The study area is located in selected wells at different oil fields in the south of Iraq. These are three wells in the Nahr Umr oilfield, one well in the Zubair oilfield, one well in the West Qurna I, two wells in the North Rumaila and one well in the South Rumaila oilfield (Table. 1), all of them having heavy crude oil in the Fatha Formation. The current study is located between longitude lines 47°14'5" -47°81' 24" and latitude circles 30°15'8"- 31° 12' 42" N) (Fig. 1).

Table 1. The tops, bottoms and thickness of the Fatha Formation in studied wells, Southern Iraq

Well Name	Field name	Top(m)	Bottom(m)	Thickness(m)
1	West Qurna	382	690	308
2	North Rumaila	276	456	180
3	South Rumaila	214	370	156
4	Nahr Umr	382	719.5	337.5
5	Nahr Umr	336	670	334
6	Zubair	360	590	230

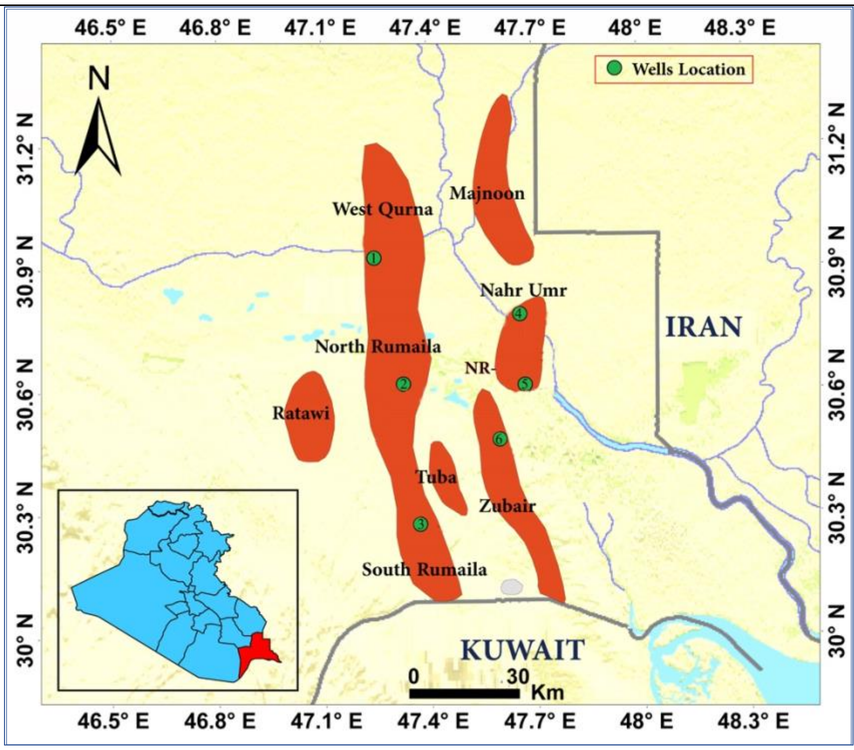


Fig. 1. The location map for the study area, the green circles represent the studied wells at different oilfields

Preparation of 100 core samples (70 samples of Nahr Umr, 30 samples of West Qurna) and 100 cutting samples (20 of North Rumaila, 20 of South Rumaila and 20 of Zubair, 20 of Nahr Umr and 20 of West Qurna) for picking to identify the critical fossils. First, dried samples, weighing about 50 g. For the picking process, the best procedure was used to extract the fossils according to Karimina et al. (2003) method, but it was modified by Al-Shawi et al. (2019). For hard limestone, hydrogen peroxide (15%) was used for 24 hours, and then wet sieving was used by a 63-micron sieve. Then, the total fossils content of samples was handpicked and counted, using flat black trays, a sable brush and a stereomicroscope. After the extraction of the fossils, they were saved in a micropaleontological slide. Two groups were identified: Foraminifera and Ostracods. Foraminifera were classified depending on Loeblich and Tappan (1988), while Ostracoda was classified according to Moore and Pitart (1961), Morkhoven (1963), and Hartman and Puri (1974).

3. Geological Setting

The Fatha Formation was deposited in the northwest-southeast oriented basin, which extended from Syria, Iraq into Iran. Fatha Formation was associated within the megasequence of Late Eocene-Recent AP11 (Sharland et al., 2001). Megasequence AP11 is associated with the collision of Neo-Tethys terrains along with the N and E sides of the Arabian Plate, also with the opening of the Gulf of Aden and the Red Sea on the S and W sides of the Arabian Plate. The opening of the Red Sea and the Gulf of Aden was associated with thermal uplift, flood basalt, and rifting during Early- Miocene (Makris and Henke, 1992). The N and NE drift of the Arabian Plate and the closure of the Neo-Tethys led to folding and thrusting along the NE margin of the Arabian Plate. The megasequence contains many formations, the Early-Mid Miocene sequence can be divided into two-second order sequences, varied with shallow water carbonates passing up into evaporites. These sequences are the Early Miocene and the Mid Miocene. The formations previously included in the Early-Mid Miocene Sequence include the Asmari, Euphrates, Serikagni, Dhiban, Kalhur Gypsum, Ghar, Jeribe, and Fatha formations (Bellen et al., 1959; Sharland et al., 2001).

The Miocene age has an important regional maximum flooding surface, the third MFS; Ng 30 is present in the middle of the Burdigalian Stage. It presents the contact between the Jeribe and Fatha formations. While the fourth MFS; Ng 40, exists in the middle of the Serravallian Stage and is marked by the contact between the Fatha Formation and the overlying Injana Formation, this stage witnessed a major change in the depositional environments from marine to continental (Sissakian et al., 2016). Tucker and Shawket (1980) stated that the absence of angular unconformities in Iraq's Tertiary sediments (only disconformities) is thought to support the hypothesis of vertical block movements and their participation in the formation of the Fatha depositional basin. The area is flat, which buried longitudinal structures of differing sizes below the Quaternary cover, separated by large synclines. The trending fold structures have an effect on the pre-tertiary layers, which are caused by the basements and faults (Al-Atabi, 2014).

The diapiric salt produced by the Infracambrian Hormoz salt series, which is thought to be underlying areas of Iraq, is most likely responsible for these structures. Negative gravity residuals' relationship with important Zubair and Nahr Umr oilfields confirms these salts (Ditmar, 1971). Structurally, the current study is located within the Zubair Subzone, it is Iraq's greatest oil-producing area and the southernmost subdivision of the Mesopotamian Zone (Al-Kaabi et al., 2023). According to Fouad (2015), the studied area is located in the Outer Platform, which is the main part of the Mesozoic Arabian plate's passive margin of the Foreland basin, exactly at Mesopotamia Foredeep and is greatly influenced by the Alpine orogenic deformation (Fig. 2). The conformable structural arrangement of the oilfields reflects the regional effect of these salts in Iran and the Arabian Gulf countries, and their comparison is very important in hydrocarbon prospecting (Christian, 1997).

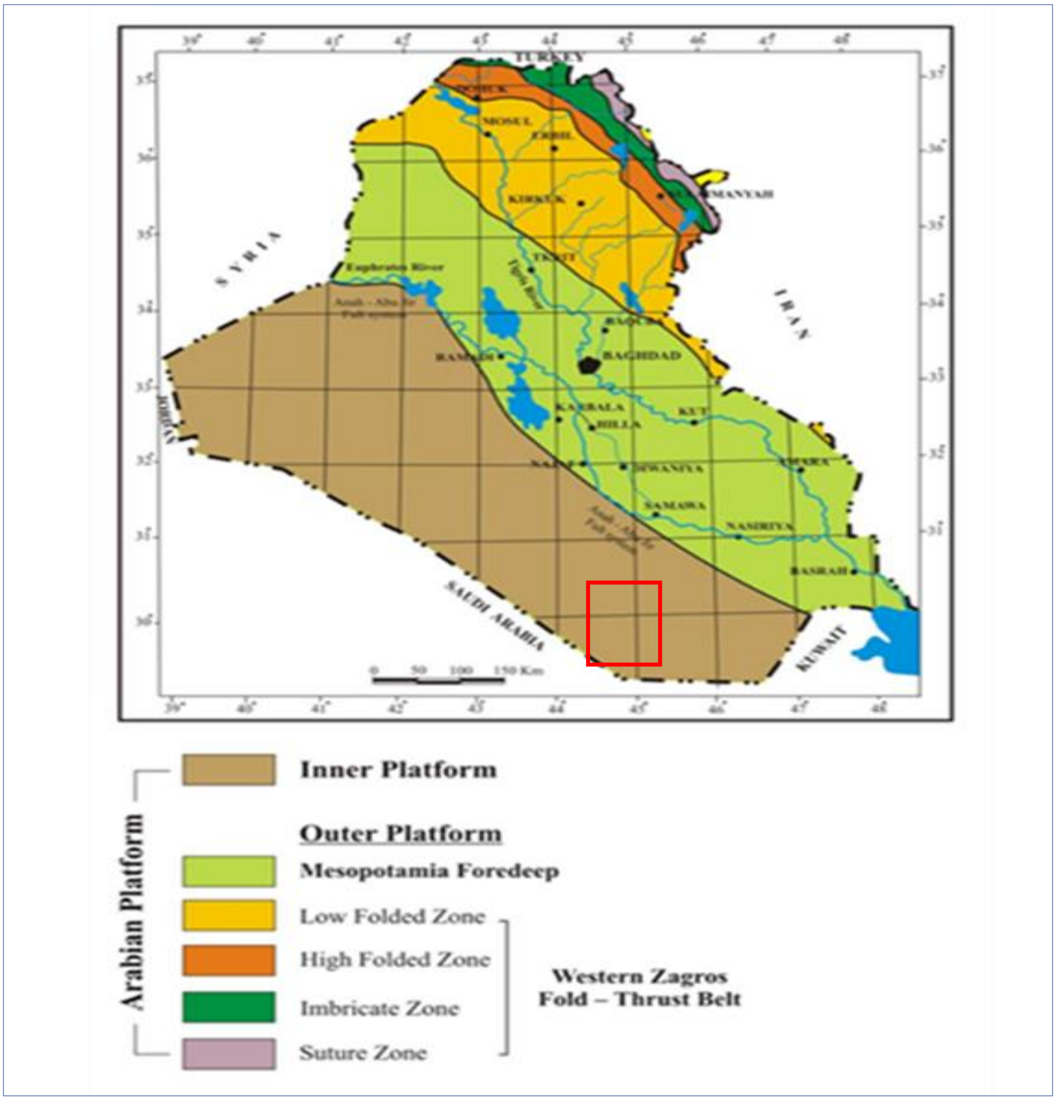


Fig. 2. The Tectonic divisions of Iraq, red square presents the study area (Fouad, 2015)

4. Results

The studied fossils focused on two types of fossils, these are Foraminifera and Ostracoda (Tables 2 and 3).

4.1. Foraminifera

Many species of foraminifera have been classified in this study based on the Loeblich and Tappan classifications (1964). 42 species belong to 21 genera of Foraminifera have been identified, among which 6 genera belong to 3 families (*Hauerinida*, *Spiroloculinidae*, *Miliamminidae*), 14 genera to 8 families (*Rotaliidae*, *Elphidiidae*, *Discorboidea*, *Nonionidae*, *Rosalinidae*, *Cibicididae*, *Cymbaloporidae Gavelinellidae*) and one genus to Family Globigerinidae, the detailed data for systematic study was summarized in Table. 2, with their photos (Plates 1 to 6). Several of identified species has characterized environments, such as:

4.1.1. Elphidium craticulatum

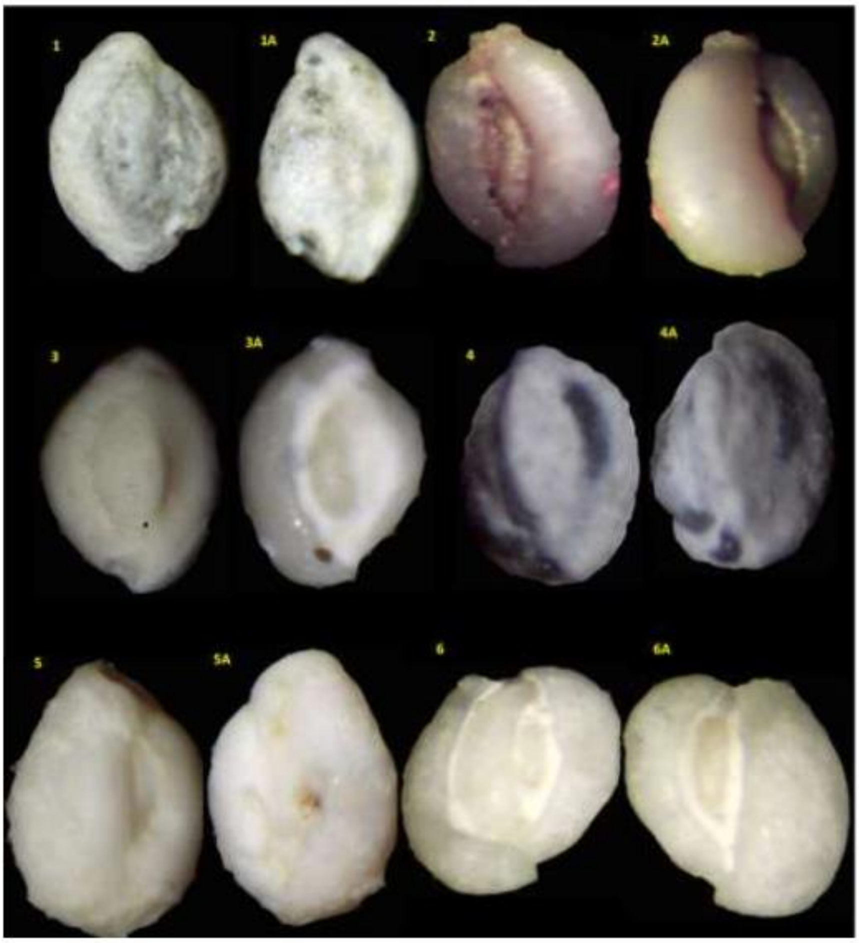
It is a public species that occur in the low tidal, and also existed in shallow subtidal with depths not exceeding twenty meters, it prefers the pure sand in normal marine salinity (Hayward et al., 1997). (Plate 4-10, and 4-10A).

Table 2. The important identified Foraminifera with systematic trends that recorded in studied wells

No.	Sub Order	Family	Genus	Species
			Pseudomassilina	*Pseudomassilina robusta*
				Quinqueloculina akneriana
				Quinqueloculina bicarinate
		Hauerinida	*Quinqueloculina*	*Quinqueloculina bubnanensis*
				Quinqueloculina laevigata
1.	Miliolina			*Quinqueloculina subdecorata*
			Siphonaperta	*Siphonaperta dilatata*
			Agglutinella	*Agglutinella laticollis*
				Spiroloculina laevigata
		Spiroloculinidae	*Spiroculina*	*Spiroculina* sp.1
				Spiroloculina sp.2
		Miliamminidae	*Miliammina*	*Miliammina fusca*
				Ammonia beccarii
				Ammonia nipponica
			Ammonia	*Ammonia parkinsoniana*
		Rotaliidae		*Ammonia pauciloculata*
				Ammonia tepida
			Asterorotalia	*Asterorotalia* sp.
			Challengerella	*Challengerella bradyi*
			Cribroelphidium	*Cribroelphidium excavatum*
				Elphidium aculeatum subsp. *norcotti*
				Elphidium advenum
				Elphidium advenums subsp. tongaense
		Elphidiidae		*Elphidium arcticum*
			Elphidium	*Elphidium bartletti*
2.	Rotaliana			*Elphidium craticulatum*
				Elphidium crispum
				Elphidium crispum waiwiriensis
				Elphidium lessonii
				Elphidium macellum
		Discorboidea	*Neoeponides*	*Neoeponides margaritifer*
			Nonion	*Nonion commune*
				Nonion fabum
		Nonionidae	*Nonionella*	*Nonionella basispinata*
				Nonionellina labradorica
			Pseudononion	*Pseudononion japonicum*
		Rosalinidae	*Rosssalina*	*Rosalina bradyi*
		Cibicididae	*Cibicides*	*Cibicides pseudoungerianus*
			Cibicidoide	*Cibicidoides bradyi*
		Cymbaloporidae	*Cymaloporella*	*Cymbaloporella tabellaeformis*
		Gavelinellidae	*Gyroidina*	*Gyroidina orbicularis*
3.	Globigerininia	Globigerinidae	*Globigerina*	*Globigerina quinquelob*

4.1.2. Elphidium incertum, and Elphidium excavatum

It indicates a shallow water environment as a lagoon (Murry, 1969). *Elphidium* was the most common genus in the study area, *Elphidium* species occur from tropical to Polar Regions, also in the intertidal zones to the continental slope (Murray 2006). The following species have been identified as belonging to this genus: *Elphidium aculeatum* subsp. *Norcotti* (Plate 4-4 and 4-5), *E.advenum* (Plate 4-6), *E. advenums Tongaense* (Plate 4-7), *E.arcticum* (Plate 4-8), *E.bartletti* (Plate 4-9), *E. craticulatum* (Plate 4-10, and 4-10A), *E. crispum* (Plate 4-11 and Plate 5-1), *E. crispum waiwiriensis* (Plate 5-2 and 5-3), *E. lessonii* (Plate 5-4), and *E. macellum* (Plate 5-5). The majority of *Elphidium* species is indicated into lagoonal environments with brackish to marina water (Rao and Rao, 1974).



Pate 1. Identified foraminifera, Miliolids group: 1-*Pseudomassilina robusta*, side view, 40X, (well. 2, 460-470 m) 1A-*Pseudomassilina robusta*, apertural view, 40X, (well. 2, 460-470 m) 2-*Quinqueloculina akneriana*, side view, 40X, (well. 2, 430-440 m, well. 4, 370-460 m) 2A- *Quinqueloculina akneriana*, apertural view, 40X, (well. 2, 430-440 m, well. 4, 370-460 m) 3-*Quinqueloculina bicarinata*, side view, 40X, (well. 3, 310-320 m) 3A-*Quinqueloculina bicarinata*, apertural view, 40 X, (well. 3, 310-320 m) 4-*Quinqueloculina bubnanensis*, side view, 40X, (well. 2, 420-430 m) 4A- *Quinqueloculina bubnanensis*, apertural view, 40X, (well. 2, 420-430 m) 5-*Quinqueloculina laevigata*, side view, 40X, (well. 6, 470-480 m, well. 4, 400-470 m) 5A- *Quinqueloculina laevigata*, apertural view, 40 X, (well. 6, 470-480 m, well. 4, 400-470 m) 6-*Quinqueloculina subdecorata*, side view, 40X, (well. 3, 350-360 m) A- *Quinqueloculina subdecorata*, apertural view, 40 X, (well. 3, 350-360 m)

4.1.3. Ammonia beccaria

It is the most frequent species in the study area after *Elphidium*, and it is distinguished by its occurrence in a variety of environments, which reflects its capability to live in a wide range of conditions. *Ammonia* species are found from the subtidal to the outer continental shelves (Schweizer and Nikulina, 2011). *Ammonia baccarii* (Plate 3-1, 3-1A, 3-2, and 3-2A), *A.parkinsoniana* (Plate 3-4, and 3-4A) and *A. tepida* (Plate 3-6, and 3-6A), these species are indicative of the brackish environment, living under conditions with temperatures between 15 - 30° C and depths not exceeding 50 m (Murray, 1969).

Plate 2. Identified foraminifera, Miliolids group: 1- *Siphonaperta dilatata* , apertural view, 40X, (well. 2, 280-290 m, 400-410 m) 2-*Agglutinella laticollis*, apertural view, 40X, (well. 2, 420-430 m) 2A-*Agglutinella laticollis*, side view, 40X, (well. 2, 420-430 m) 3-*Spiroloculina laevigata*, side view, 40X, (well. 2, 310-320 m, well. 5, 510-540 m) 3A- *Spiroloculina laevigata*, apertural view, 40X (well. 2, 310-320 m, well. 5, 510-540 m) 4-*Spiroculina* sp.1, side view, 40X, (well. 3, 280-290 m) 4A-*Spiroculina* sp.1, apertural view, 40X, (well. 3, 280-290 m) 5-*Spiroloculina* sp. 2, apertural view, 40X, (well. 3, 310-320 m) 5A- *Spiroloculina* sp. 2, side view, 40X, (well. 3, 310-320 m) 6-*Miliammina fusca*, side view, 40X, (well. 2, 290-300 m, well. 6, 490-500 m) 6A-*Miliammina fusca*, apertural view, 40X, (well. 2, 290-300 m, well. 6, 490-500 m)

4.1.4 Quinqueloculina

It is genus lives in a variety of environments, including marine and lagoonal environments, also with high salinity conditions (Boltoveskoy and Wright, 1976). According to Murray (2006), the Miliolids family dominates hypersaline marshes and natural marine environments. The reef flat and lagoonal area is dominated by a *Quinqueloculina* (Abu-Zied et. al., 2016). The following species have been identified as belonging to this genus: *Quinqueloculina akneriana* (Plate 1-2, and 1-2A), *Q.bicarinata* (Plate 1-3, and 1-3A), *Q.bubnanensis* (Plate 1-4, 1-4A), *Q.laevigata* (Plate 1-5, and 1-5A), *Q.subdecorata* (Plate 1-6, and 1-6A).

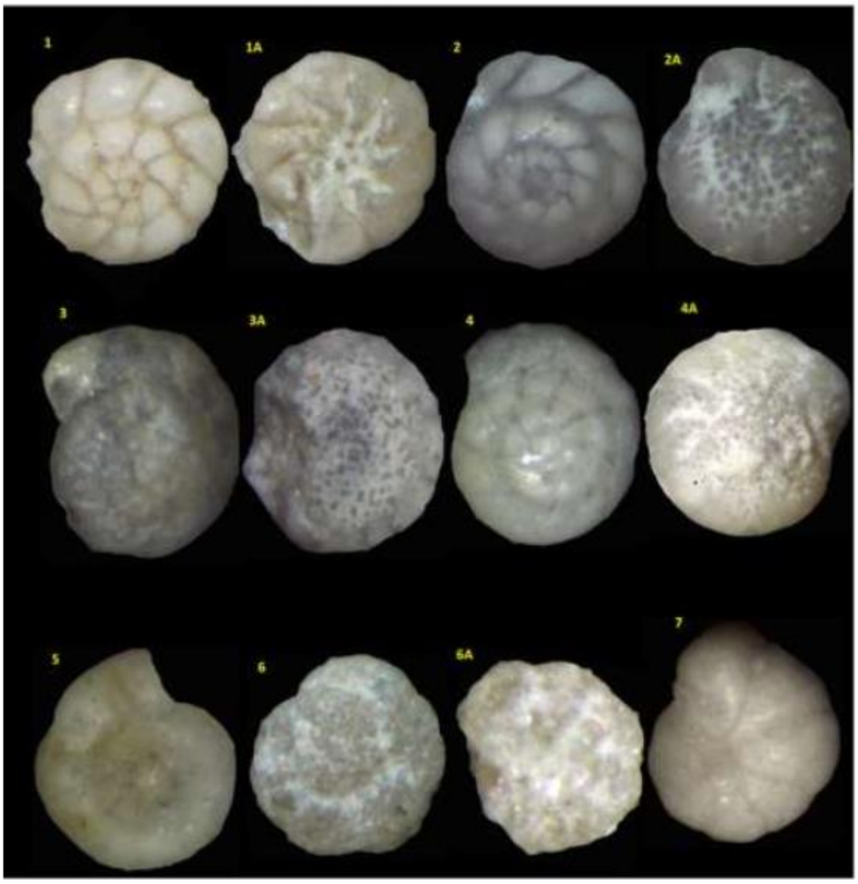


Plate 3. Identified foraminifera, Ammonoids group: 1-*Ammonia beccarii*, spiral side, 40X, (well. 2, 290-440 m, well. 4, 300-510 m) 1A- *Ammonia beccarii*, umbilical side, 40X, (well. 2, 290-440 m, well. 4, 300-510 m) 2-*Ammonia beccarii*, spiral side, 40X, (well. 2, 290-440 m, well. 4, 300-510 m) 2A- *Ammonia beccarii*, umbilical side, 40X, (well. 2, 290-440 m, well. 4, 300-510 m) 3-*Ammonia nipponica*, spiral side, 40X, (well. 2, 290-300 m, 310-320 m, well. 3, 250-270 m) 3A -*Ammonia nipponica*, umbilical side, 40X, (well. 2, 290-300 m, 310-320 m, well. 3, 250-270 m) 4- *Ammonia parkinsoniana*, spiral side, 40X, (well. 2, 280-290 m) 4A- *Ammonia parkinsonian*, umbilical side, 40X, (well. 2, 280-290 m) 5-*Ammonia pauciloculata*, spiral side, 40X, (well. 2, 290-380 m, well. 4, 420-510 m) 6-*Ammonia tepida*, spiral side, 40X, (well. 2, 310-340 m, well. 3, 290-350 m) 6A- *Ammonia tepida*, umbilical side, 40X, (well. 2, 310-340 m, well. 3, 290-350 m) 7- *Asterorotalia* sp., spiral side, 40X, (well. 2, 350-360 m, well. 3, 320-330 m)

4.1.5. Spiroloculina

Spiroloculina laevigata refers to a lagoon environment with marine waters, also recorded at tidal flats environments (Belkovskoy and Wright, 1976). It is indicated that the intertidal-subtidal assemblage is positively correlated with high salinity and temperature (Al-Dubai et al., 2017) (Plate 2-3, 2-3A, 2-4, 2-4A, 2-5, and 2-5A).

4.2. Ostracoda

Forty species related to thirty genera of Ostracoda have been identified in this study, depending on the classification of Moore and Pitart (1961), Morkhoven, (1963); and Hartman and Puri, (1974), two genera belong to family Cytheridea, three genera to family Leptocytheridae, two genera belong to family Cytherellidae, four genera belong to family Cytherideidae, one genus belong to family Cytherettidae, one genus belong to family Krithidae and finally one genus belong to family Trachyleberididae, the detailed information about classification illustrated in Table 3; Plates 7 to 11.

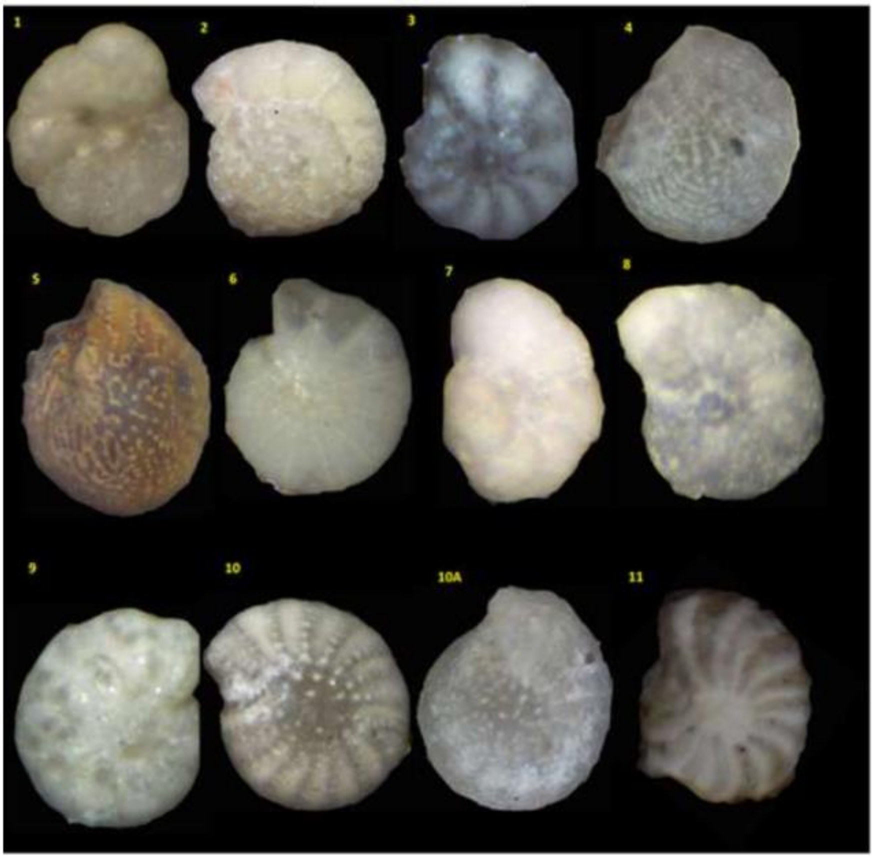


Plate 4. Identified foraminifera, Elphidiinae family: 1-*Asterorotalia* sp., umbilical side, 40X, (well. 2, 350-360 m, well. 3, 320-330 m, well. 5, 300-410 m) 2-*Challengerella bradyi* , spiral side, 40X,(well. 3, 230-240 m) 3-*Cribroelphidium excavatum*, spiral side, 40X, (well. 2, 290-310 m, well. 5, 500-520 m) 4-*Elphidium aculeatum* subsp. *norcotti,* spiral side view, 40X, (well. 3, 240-250 m, 300-310 m, 330-340 m) 5-*Elphidium aculeatum* subsp. *norcotti,* spiral side, 40X, (well. 3, 240-250 m, 300-310 m, 330-340 m) 6-*Elphidium advendum,* spiral side, 40X, (well. 3, 310-320 m, well. 2, 290-300 m, 420-450 m, well. 1, 400-510 m) 7-*Elphidium advenums subsp. tongaense,* spiral side, 40X, (well. 3, 310-320 m, well. 2, 290-300 m, 420-450 m, well. 1, 400-510 m). 8-*Elphidium arcticum,* spiral side, 40X, (well. 3, 240-25 m, 310-320 m, well. 6, 500-510 m) 9-*Elphidium bartletti,* spiral side, 40X, (well. 3, 240-25 m, 310-320 m, well. 6, 500-510 m) 10-*Elphidium craticulatum,* spiral side, 40X, (well. 2, 290-450 m, well. 3, 216-370 m, well. 6, 260-560 m, well. 1, 300-460 m) 10A-*Elphidium craticulatum,* umbilical side, 40X, (well. 2, 290-450 m, well. 3, 216-370 m, well. 6, 260-560 m, well. 1, 300-460 m) 11-*Elphidium crispum,* spiral side, 40X, (well. 2, 450-460 m, well. 3, 310-330 m)

On the basis of Ostracoda that recorded from the Fatha Formation in the study areas. Many genera were identified for Ostracoda in this study which are indicator environment such as:

4.2.1. Callistocythere

This genus indicates shallow water environment Khalaf, 1984. Species of this genus are predominantly surface dwellers on sandy mud, sand or algae from the littoral to eulittoral zones (Manh and Tsukagoshi, 2015) (Plate 7-9).

4.2.2. Cytherella

It is genus indicates inner to middle neritic environment indicates open, shallow marine environmental (Morkhoven. 1963) (Plate 8-3).

Table 3. The Family, genera and species of Ostracoda that recorded in the present study

Family	Genus	Species
Cytheridea	*Schneiderella* sp.	*Schneiderella* sp. *Schneiderella unispinata* *Schneiderella vulgaris* sp.nov.
	Sulcostocythere	*Sulcostocythere dimorphica* sp.nov. *Sulcostocythere posterotruncata* sp.nov. *Sulcostocythere postronodosa* sp.nov.
Leptocytheridae	Leptocythere(*Leptocythere*)	*Leptocythere (Leptocythere) hajerensis* sp. nov.
	Callistocythere	*Callistocythere* sp.
	Dohukia	*Dohukia fossulata* gen.et.sp.nov.
Cytherellidae	*Cytherella*	*Cytherella dohukensis* sp. nov.
	Cytherelloidea	*Cytherelloidea flexicostata*
Cytherideidae	*Cyprideis*	*Cyprideis torosa*
	Miocyprideis	*Miocyprideis ovalis* *Miocyprideis recta* sp. nov.
	Neocyprides	*Neocyprides* sp.
	Hemicyprideis	*Hemicyprideis angulata angulata*
Cytherettidae	*Flexus*	*Flexus trifurcata*
Cytheruridae	*Paijenborchallina* (*Eopaijenborchalla*)	*Paijenborchallina* (*Eopaijenborchalla*) *iraqensis*
	Semicytherura	*Semicytherura matiaensis* sp. nov.
Krithidae	*Dentokrithe*	*Dentokrithe comma* *Dentokrith aff. Dentokrithe indica*
Trachyleberididae	*Actinocythereis*	*Actinocythereis iraqensis* *Actinocythereis cornuocula cornuocula* sp.nov.subsp.nov. *Acantocythereis dohukensis*
	Alocopocythere	*Alocopocythere fossularis*
	Asymmetricythere	*Asymmetricythere reticulata* sp. nov.
	Gyrcythere	*Gyrcythere siddiquii*
	Hermanites	*Hermanites transversicostata*
	Isbuntonia	*Isbuntonia pulchra* sp. nov.
	Keijella	*Keijella* sp.
	Stigmatocythere	*Stigmatocythere cellulosa* sp. nov.
	Quadracythere	*Quadracythere* (*Mosulia*) *Pulchra* sp. nov.
Loxoconchidae	*Loxoconcha*	*Loxoconcha hamrinensis*
	Phlycocythere	*Phlycocythere* sp.
Paracyprididae	*Pontocyprella*	*Pontocyprella kirkukensis* sp. nov.
Paracytherideidae	*Paracytheridea*	*paracytheridea splendida* sp. nov.
Propontocyprididae	*Propontocypris*	*Propontocypris cuneiformis* variant A *Propontocypris miocaenica* sp. nov. *Propontocypris solitaria*
Bythocyprididae	*Bythocypris* sp.	*Bythocypris* sp. A

4.2.3 Leptocythere

Some species of this genus typically occur in estuarine (brackish water) environments, while others are mainly found in shallow marine (littoral) environments (Morkhoven, 1963). It is abundant and widely distributed across the shallow seawaters stretching from the tropics to the subarctic zone, including the water (Shurupova and Tesakovab, 2021) (Plate 7-8).

4.2.4. Loxoconcha

This genus indicates a brackish environment (a very shallow environment with brackish conditions, well developed nodes) (Khalaf, 1984). It can be concluded that shallow marine, littoral and transitional facies conditions (Tunoglu, 2001) (Plate 11-5).

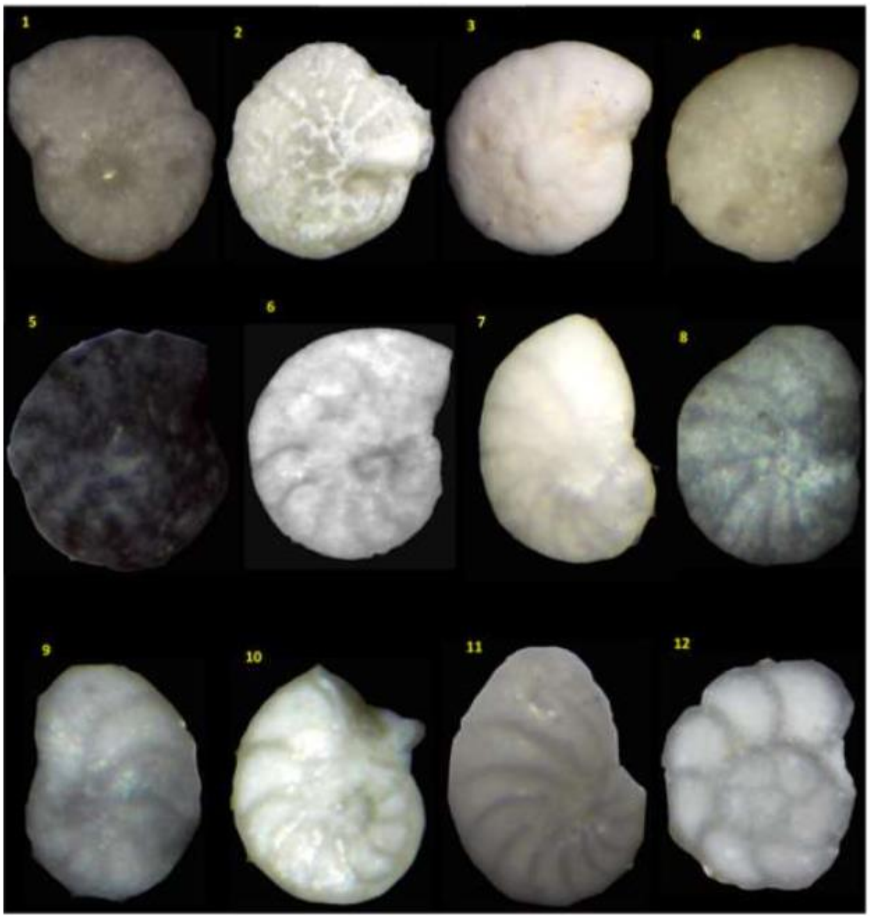


Plate 5. Identified foraminifera, Elphidiinae and Nonionidae families: 1-*Elphidium crispum* , spiral side , 40X, (well. 2, 450-460 m, well. 3, 310-330 m) 2-*Elphidium crispum waiwiriensis,* spiral side, 40X, (well. 3, 240-250 m, 300-340 m, well. 6, 420-430 m) 3-*Elphidium crispum waiwiriensis*, spiral side, 40X, (well. 3, 240-250 m, 300-340 m, well. 6, 420-430 m) 4-*Elphidium lessonii* , spiral side, 40X, (well. 2, 210-440 m, well. 3, 230-240 m, 330-350 m) 5-*Elphidium macellum,* spiral side, 40X, (well. 6, 490-500 m, well. 1, 470-560 m) 6-*Neoeponides margaritifer,* spiral side, 40X, (well. 3, 320-330 m) 7-*Nonion commune,* spiral side, 40X, (well. 3, 320-330 m) 8-*Nonion fabum,* spiral side, 40X, (well. 3, 300-340 m, well. 1, 400-420 m) 9-*Nonionella basispinata,* spiral side, 40X, (well. 3, 320-340 m) 10-*Nonionellina labradorica,* spiral side, 40X, (well. 3, 310-320 m)11-*Pseudononion japonicum,* spiral side, 40X, (well. 2, 400-410 m) 12-*Rosalina bradyi,* spiral side, 40X, (well. 2, 290-330 m, 400-430 m)

4.3. Biozonation

Biostratigraphic zones were conducted based on the results of the identified foraminifera and Ostracoda genera depending on thin sections and picking samples, which covered the Middle Miocene in the study area. In order to summarize the results of the current study, all the biozone trends of the identified fossils have been placed within one table for all the studied wells, because most of the extending fossils are located in each well somewhat similar, so making repeated tables for each well will increase the pages of the article. Therefore, the biozones were illustrated in the Figs. 3 and 4; Table 4. It is worth mentioning, that most of the vertical extensions of some genera are missed because of the deposition of evaporite and clastic beds. After plotting the extensions for each fossil, the study suggested these biozones for foraminifera and Ostracoda.

4.3.1. Elphidium craticulatum total range zone

Recorded in wells 2, 3 and 6, this biozone was first recorded in Fatha Formation, as well as choosing this species *Elphidium craticulatum* (Plate 4-10 and 4-10A) for the first time as taxon range biozone. The thickness of the biozone is varied, in well. 2 reaches to 270 m, well. 3 about 164 m and well. 6 reaches to 110 m. It began with the appearance of *Ammonia tepida* (Plate 3-6 and 3-6A), *Elphidium arcticum* (Plate 4-8), and ended with the species *Cribroelphidium excavatum* (Plate4, Fig. 3), *Miliammina fusca* (Plate 2-6, and 2-6A), *Cibicidoides bradyi* (Plate 4-2), *Elphiduim. Advenum* (Plate 4-6, and 4-7).

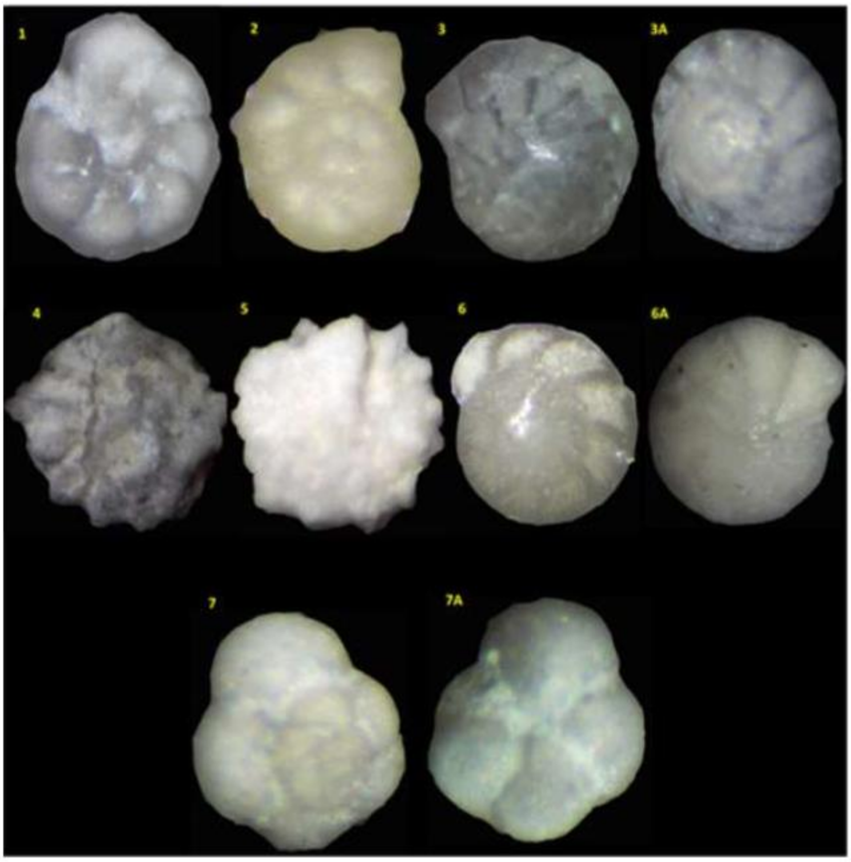


Plate 6. Identified Foraminifera, other diagnosed families: 1-*Rosalina Brady*, spiral side, 40X, (well. 2, 290-330 m, 400-430 m) 2-*Cibicides pseudoungerianus*, spiral side, 40X, (well. 2, 290-300 m, well. 1, 260-280 m) 3-*Cibicidoides Brady*, spiral side, 40X, (well. 2, 290-300 m, 400-420 m) 3A-*Cibicidoides Brady*, spiral side, 40X, (well. 2, 290-300 m, 400-420 m) 4. *Cymbaloporella tabellaeformis*, spiral side, 40X, (well. 2, 450-460 m, well. 6, 400-420 m) 5-*Cymbaloporella tabellaeformis*, spiral side, 40X, (well. 2, 450-460 m, well. 6, 400-420 m) 6-*Gyroidina orbicularis*, spiral side, 40X, (well. 3, 300-310 m) 6A. *Gyroidina orbicularis*, umbilical side, 40X, (well. 3, 300-310 m) 7-*Globigerina quinqueloba*, spiral side, 40X, (well. 3, 240-250 m, well.1, 290-300 m) 7A. *Globigerina quinqueloba*, umbilical side, 40X, (well. 3, 240-250 m, well. 1, 290-300 m)

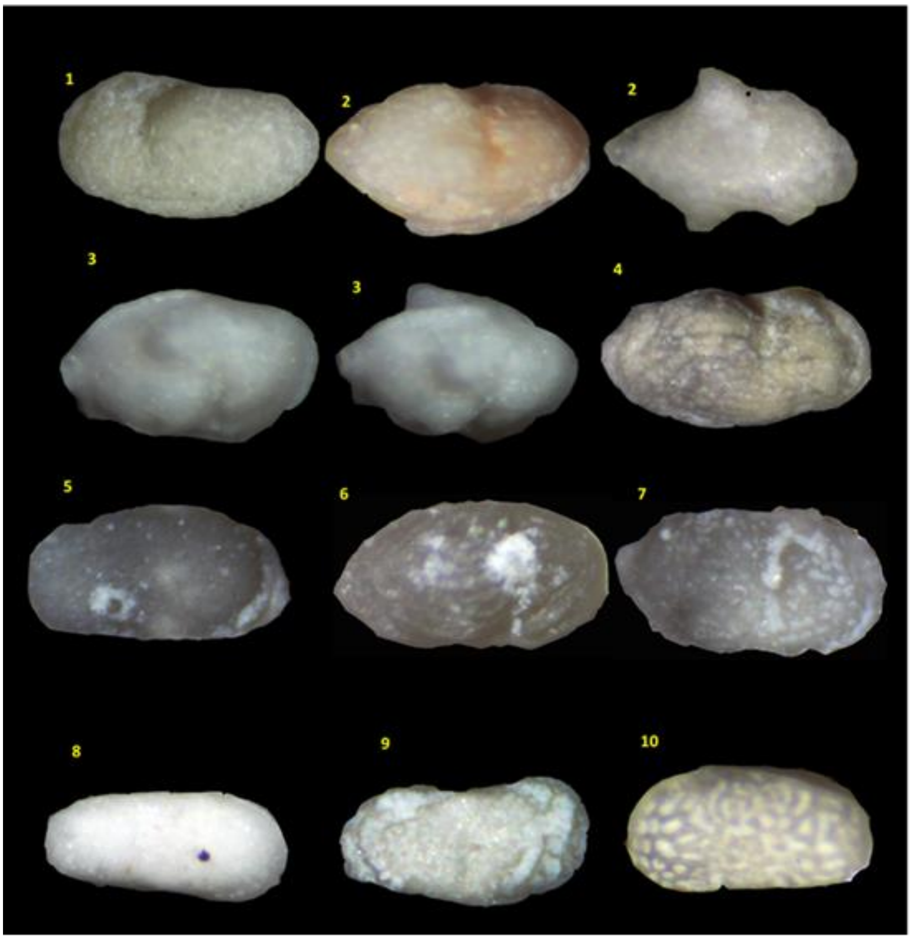


Plate 7. Identified Ostracoda, Cytheridea and Leptocytheridae Families: 1-*Schneiderella* sp., external view, 40X, (well. 2, 300-420 m, well. 3, 216-340 m, well. 6, 420-510 m, well. 1,300-530 m) 2-*Schneiderella unispinata*, external view, 40X, (well. 2, 300-420 m, well. 3, 216-340 m, well. 6, 420-510 m, well. 1, 300-530 m) 2A-*Schneiderella unispinata,* dorsal view, 40X, (well. 2, 300-420 m, well. 3, 216-340 m, well. 6, 420-510 m, well. 1, 300-530 m) 3-*Schneiderella unispinata,* external view, 40X, (well. 2, 300-420 m, well. 3, 216-340 m, well. 6, 420-510 m, well. 1, 300-530 m) 3A-*Schneiderella unispinata*, dorsal view, 40 X, (well. 2, 300-420 m, well. 3, 216-340 m, well. 6, 420-510 m, well. 1, 300-530 m) 4-*Schneiderella vulgaris* sp. nov., external view, 40 X, (well. 2, 310-320 m, well. 3, 240-250 m, 270-280 m) 5- *Sulcostocythere dimorphica* sp. nov., external view, 40 X, (well. 2, 290-300 m, 340-350 m, well. 1, 290-300 m) 6- *Sulcostocythere posterotruncata* sp. nov., external view, 40 X, (well. 2, 290-330 m, well. 6, 300-320 m) 7-*Sulcostocythere postronodosa* sp. nov., external view, 40 X, (well. 2, 320-360 m, 460-470 m) 8- *Leptocythere (Leptocythere) hajerensis* sp.nov., external view, 40 X, (well. 2, 320-330 m, well. 6, 460-470 m) 9- *Callistocythere* sp., external view, 40 X, (well. 2, 320-330 m, well. 3, 330-340 m, well. 1, 340-350 m) 10- *Dohukia fossulata* gen.et. sp. nov., external view, 40 X, (well. 2, 310-320 m, well. 3, 240-280 m)

It could be equivalent to the *Ammonia beccaria* taxon range biozone that was determined by Al-Asadi (2002) (Table. 4), but this genus could continue until to modern ages, it was recorded in the middle Holocene (Al-Jaberi and Mahdi, 2020), so this species may cause confusion in some of the results. Also, *Elphidium craticulatum* taxon range zone could be an assemblage zone because most of the recorded fossils falls within it, such as *Ammonia beccarii* (Plate 3-1, 3-1A, 3-2, and 3-2A), *A.nipponica* (Plate 3-3, and 3-3A), *A. parkinsoniana* (Plate 3-4, and 3-4A) . *A.pauciloculata* (Plate 3-5), *A.tepida* (Plate 3-6, and 3-6A), *Agglutinella laticollis* (Plate 2-2, and 2-2A), *Asterorotalia* sp. (Plate 4-1), *Challengerella bradyi* (Plate 4-2), *Cibicidoides bradyi* (Plate 6-3, and 6-3A), *C.pseudoungerianus* (Plate 6-

2),*Cribroelphidium excavatum* (Plate 4-3), *Cymbaloporella tabellaeformis* (Plate 6-4, and 6-5), *Elphidium aculeatum* subsp. *Norcotti* (Plate 4-4, and 4-5), *E. advenum* (Plate 4-6), *E.advenums* sub sp. *Tongaense* (Plate 4-7), *E.arcticum* (Plate 4-8), *E.bartletti* (Plate 4-6), *E.crispum* (Plate 4-11, Plate 5-1), *E.crispum waiwiriensis* (Plate 5-2, and 5-3), *E. lessonii* (Plate 5-4), *Gyroidina orbicularis* (Plate 6-6, and 6-6A), *Miliammina fusca* (Plate 2-6, and 2-6A), *Neoeponides margaritifer* (Plate 5-6), *Nonion commune* (Plate 5-7), *N. fabum* (Plate 5-8),*Nonionella basispinata* (Plate 5-9), *Nonionellina labradorica* (Plate 5-10), *Pseudo onion japonicum* (Plate 5-11), *Quinqueloculina bicarinata* (Plate 1-3, and 1-3A), *Q. bubnanensis* (Plate 1-4, and 1-4A), *Q.laevigata* (Plate 1-5, and 1-5A), *Q. subdecorata* (Plate 1-6, and 1-6A), *Siphonaperta dilatata* (Plate 1-1), *Spiroloculina laevigata* (Plate 1-3, and 1-3A), *Rosalina bradyi* (Plate 5-12). Also recorded one species followed to planktonic foraminifer which is *Globigerina quinqueloba* (Plate 6-7, 6-7A), it presents a good index to the middle Miocene age (Adegoke et al., 2017).

Plate 8. Identified Ostracoda, Cytherellidae and Cytherideidae families:1-*Cytherelloidea flexicostata*, external view, 40X, (well. 2, 290-300 m, well. 3, 216-220 m, 280-290 m) 2-*Cytherelloidea flexicostata*, external view, 40X, (well. 2, 290-300 m, well. 3, 216-220 m, 280-290 m) 3-*Cytherella dohukensis* sp. ov. , external view, 40 X, (well. 3, 300-310 m, well. 1, 320-340 m) 4-*Cyprideis torosa*, external view, 40X, (well. 2, 290-350 m, 380-390 m, well. 3, 230-240 m, well. 6, 470-500 m) 5-*Miocyprideis ovalis*, external view, 40X, (well. 2, 290-340 m, 420-460 m, well. 1, 400-420 m) 6-*Miocyprideis recta* sp. nov., external view, 40 X, (well. 2, 290-230 m, 320-330 m, well. 1, 340-350 m) 7-*Neocyprides* sp., external view, 40 X, (well. 2, 290-330 m, well. 6, 500-510 m) 8-*Hemicyprideis angulata angulata*, external view,

40X, (well. 2, 290-330 m, well. 3, 261-260 m, 300-350 m) 9-*Flexus trifurcate*, external view, 40X, (well. 2, 320-350 m, well. 3, 240-350 m)10-*Paijenborchallina (Eopaijenborchalla) iraqensis,* external view, 40X, (well. 2, 330- 340 m, well. 3, 300-330 m). 10A-*Paijenborchallina (Eopaijenborchalla) iraqensis,* dorsal view 40X, (well. 2, 330-340m, well. 3, 300-330m). 11-*Semicytherura matiaensis* sp. nov., external view, 40 X, (well. 3, 320-330 m, well. 1, 310-320m)

Plate 9. Identified Ostracoda, Trachyleberididae Family: 1-*Dentokrithe comma*, external view, 40X, (well. 2, 310-330 m, 420-430 m, well. 3, 280-330 m, well. 6, 500-510 m) 2-*Dentokrith aff. Dentokrithe indica*, external view, 40X, (well. 1, 320-340 m, well. 2, 350-360 m) 3-*Actinocythereis iraqensis*, external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 4-*Actinocythereis iraqensis,* external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 5-*Actinocythereis iraqensis,* external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 6-*Actinocythereis iraqensis,* external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 7-*Actinocythereis iraqensis,* external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 8-*Actinocythereis iraqensis*, external view, 40X, (well. 2, 290-470 m, well. 3, 210-360m, well. 6, 460-550 m, well. 1, 300-400 m) 9-*Actinocythereis iraqensis,* external view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m) 9 A -*Actinocythereis iraqensis,* dorsal view, 40X, (well. 2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m). 10- *Actinocythereis iraqensis,* external view, 40X, (well.2, 290-470 m, well. 3, 210-360 m, well. 6, 460-550 m, well. 1, 300-400 m). 11- *Actinocythereis cornuocula cornuocula* sp. nov., external view, 40X, (well. 3, 320-340 m, well. 6, 470-480 m)

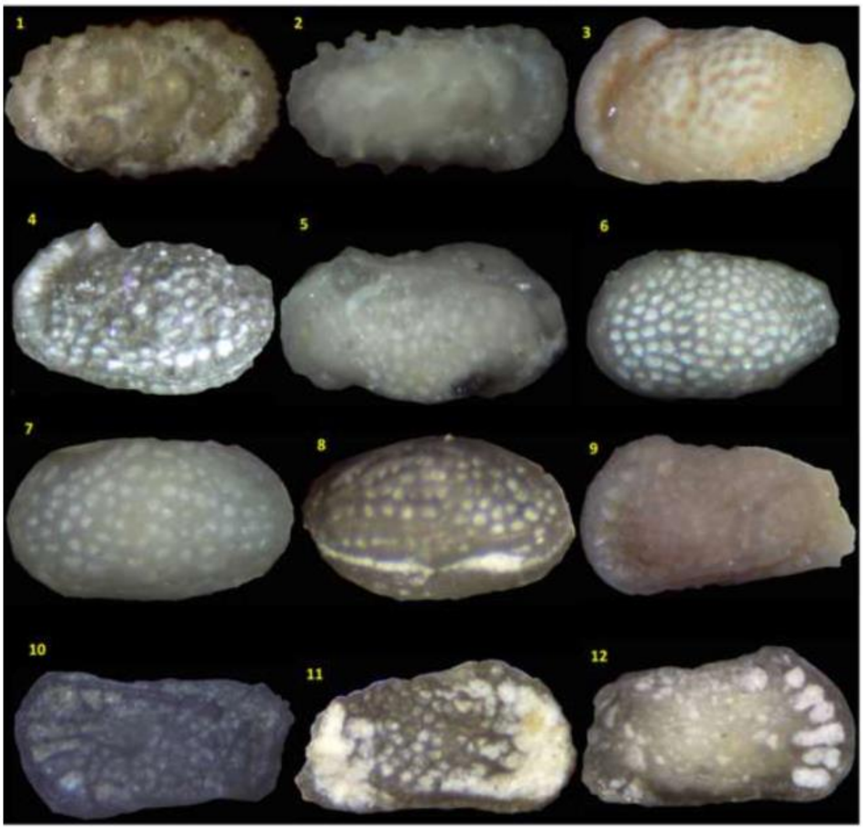


Plate 10. Identified Ostracoda, Trachyleberididae Family: 1-*Actinocythereis cornuocula cornuocula* sp. nov., external view, 40X, (well. 3, 320-340 m, well. 6, 470-480 m) 2-*Acantocythereis dohukensis*, external view, 40X, (well. 1, 420-450 m, well. 6, 460-470 m) 3-*Alocopocytherefossularis*, external view, 40X, (well. 2, 290-390 m, well. 3, 216-340 m) 4-*Alocopocythere fossularis* external view, 40X, (well. 2, 290-390 m, well. 3, 216-340 m) 4A-*Alocopocythere fossularis*, external view, 40X, (well. 2, 290-390 m, well. 3, 216-340 m) 5- *Alocopocythere fossularis*, external view, 40X, (well. 2, 290-390 m, well. 3, 216-340 m) 6-*Asymmetricythere reticulata* sp. nov., external view, 40X, (well. 2, 290-390 m, well. 3, 230-330 m, well. 6, 480-510 m) 7-*Gyrcythere siddiquii,*external view, 40X, (well. 2, 290-330 m, well. 3, 240-250 m, well. 6, 470-510 m) 8-*Gyrcythere siddiquii*, external view, 40X, (well. 2, 290-330 m, well. 3, 240-250 m, well. 6, 470-510 m) 9-*Hermanites transversicostata,* external view, (well. 2, 290-330 m, well. 3, 216-360 m) 10- *Hermanites transversicostata,* external view, (well. 2, 290-330 m, well. 3, 216-360 m) 11- *Hermanites transversicostata,* external view, (well. 2, 290-330 m, well. 3, 216-360 m) 12-*Hermanites transversicostata,* external view, 40X, (well. 2, 290-330 m, well. 3, 216-360 m)

4.3.2. Schneiderella unispinata assemblage zone

This biozone was first recorded in the Fatha Formation; it presents in wells 2, 3 and 6. The thickness of the biozone is 150 m in well. 2, 166 m in well. 3 and 110 m in well. 6. The bottom contact determined by first appearance of *Schneiderella unispinata (*Plate 7-2, 7-2A, 7-3, and 7-3A), *Actinocythereis iraqensis (*Plate 9-3, 9-4, 9-5, 9-6, 9-7, 9-8, 9-9, 9-9A, and 9-10), *Alocopocythere fossularis* (Plate 10-3, 10-4, 10-4A, and 10-5), *Asymmetricythere reticulata* sp. nov. (Plate 10-6), *Flexus trifurcate* (Plate 8-9), *Hemicyprideis angulate angulate* (Plate 8-8), *Hermanites transversicoststs* (Plate 10-9, 10-10, 10-11, and 10-12), *Semicytherura matiaensis* sp. nov. (Plate 8-11), *Stigmatocythere cellulosa* sp. nov. (Plate 11-3) while the upper contact is determining with disappearance of *Schneiderella unispinata* with other species such as *Actinocythereis iraqensis, Alocopocythere fossularis*, *Asymmetricythere reticulata* sp. nov., *Miocyprideis ovalis* (Plate 8-5), *Miocyprides recta* sp. nov. (Plate 8-6), *Neocyprides* sp. (Plate 8-

10), *Sulcostocythere dimorphica* sp. nov. (Plate 7-5), *Sulcostocythere posterotruncata* sp. nov. (Plate 7-4 and 7-6) (Table. 5).

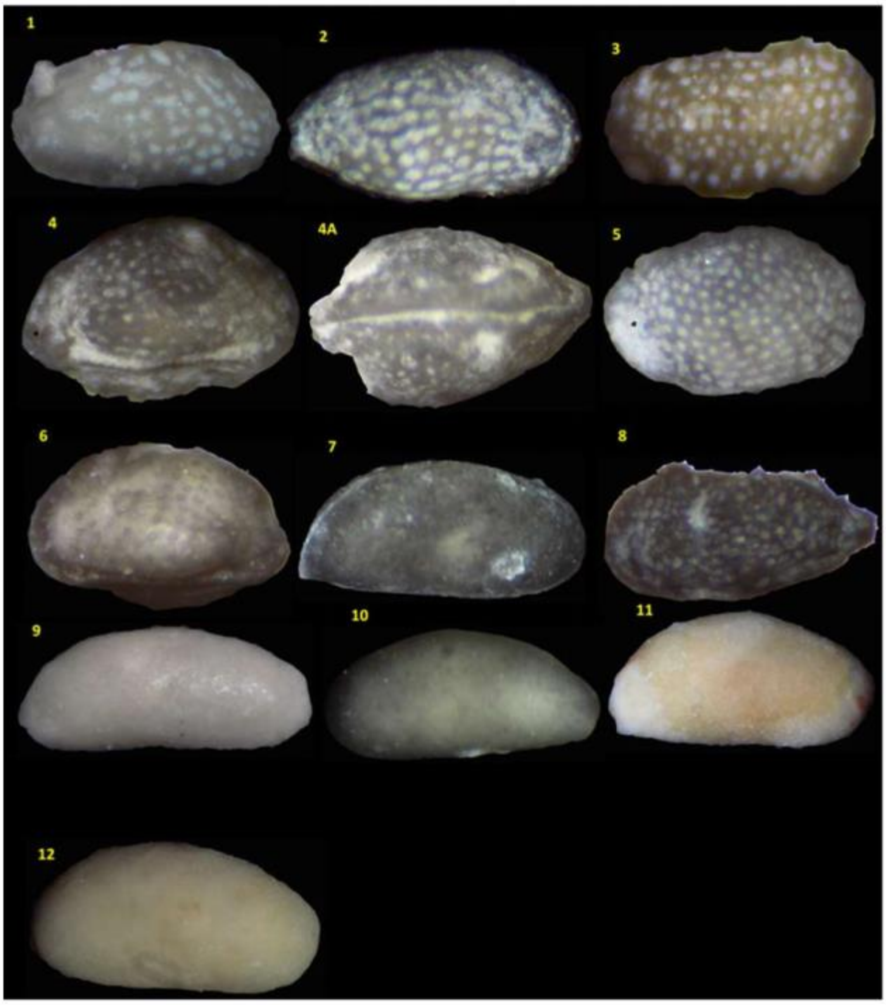


Plate 11. Identified Ostracoda, the other diagnosed families: 1-*Isbuntonia pulchra* sp. nov., external view, 40X, (well. 2, 310-320 m, 350-360 m, well. 3, 250-260 m) 2-*Keijella* sp., external view, 40X, (well. 2 ,290-330 m, 380-390 m, well. 3, 240-290 m, well. 6, 480-510 m) 3- *Stigmatocythere cellulosa* sp. nov., external view, 40X, (well. 2, 310-330 m, well. 6, 300-340 m) 4-*Quadracythere* (*Mosulia*) Pulchra sp.nov., external view, 40X, (well. 2, 320-330 m, well .3, 360-37 0m) 4A- *Quadracythere* (*Mosulia*) Pulchra sp.nov., dorsal view, 40X, (well. 2, 320-330 m, well. 3, 360-370 m) 5-*Loxoconcha* (*Loxoconcha*) *hamrinensis*, external view, 40X, (well. 2, 320-330m, well. 3, 240-250 m, well. 6, 460-470 m) 6- *Phlycocythere* sp., external view, 40X, (well. 1, 340-350 m, well. 2, 310-370 m) 7-*Pontocyprella kirkukensis* sp. nov., external view, 40X, (well. 3, 310-320 m, well. 6, 470-480 m) 8-*paracytheridea splendida* sp. nov., external view, 40X, (well. 3, 320-330 m, well. 6, 460-470 m) 9-*Propontocypris cuneiformis* variant A, external view, 40X, (well. 1, 340-350 m, well. 3, 300-310 m) 10- *Propontocypris miocaenica* sp. nov., external view, 40X, (well. 3, 350-360 m) 11- *Propontocypris solitaria*, external view, 40X, (well. 1, 400-410 m, well. 2, 360-370 m) 12- *Bythocypris* sp. A, external view, 40X, (well. 2, 340-350 m)

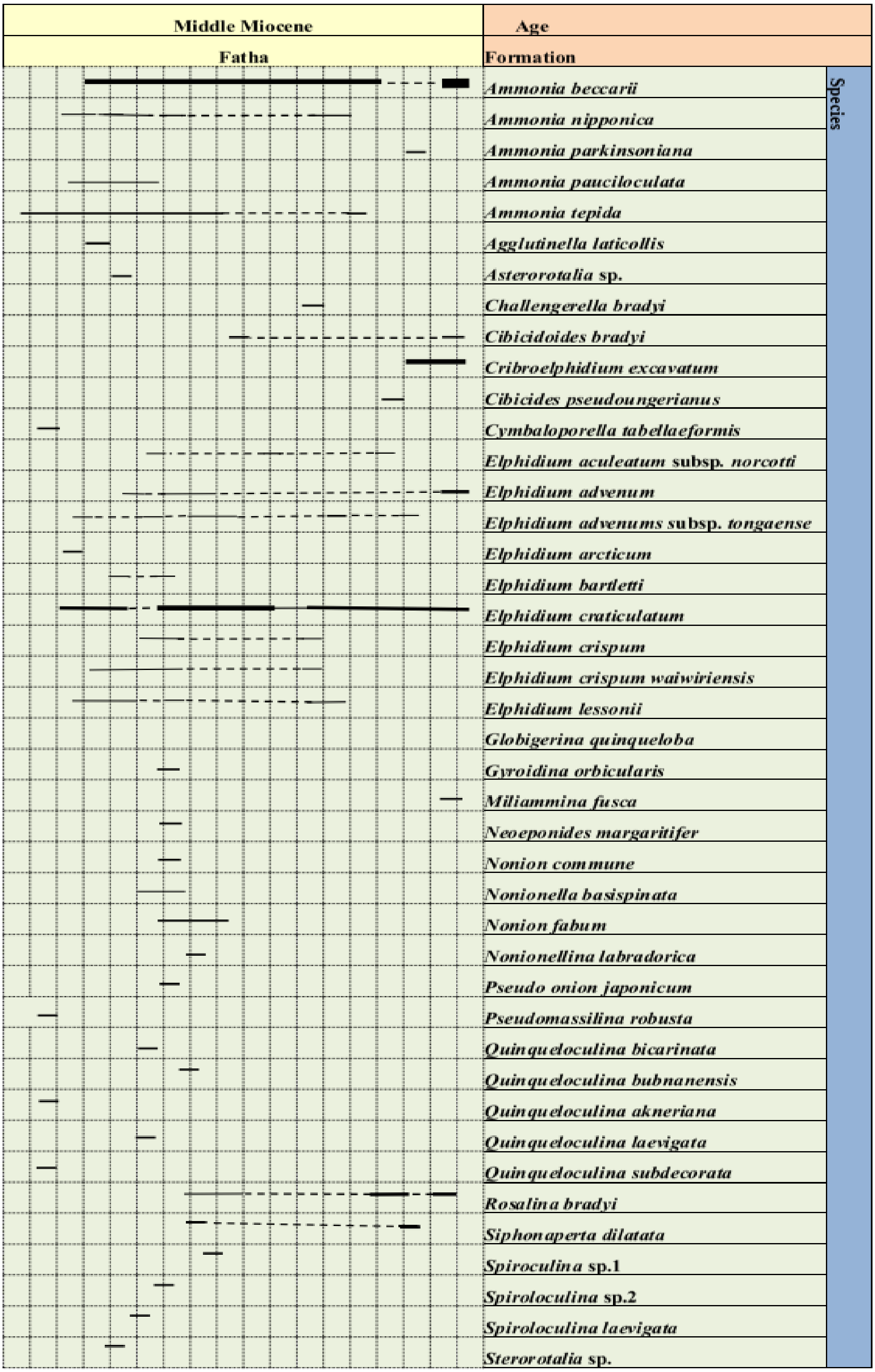


Fig. 3. Biostratigraphic occurrence of identified Foraminifera for Fatha Formation in the studied wells, Southern Iraq

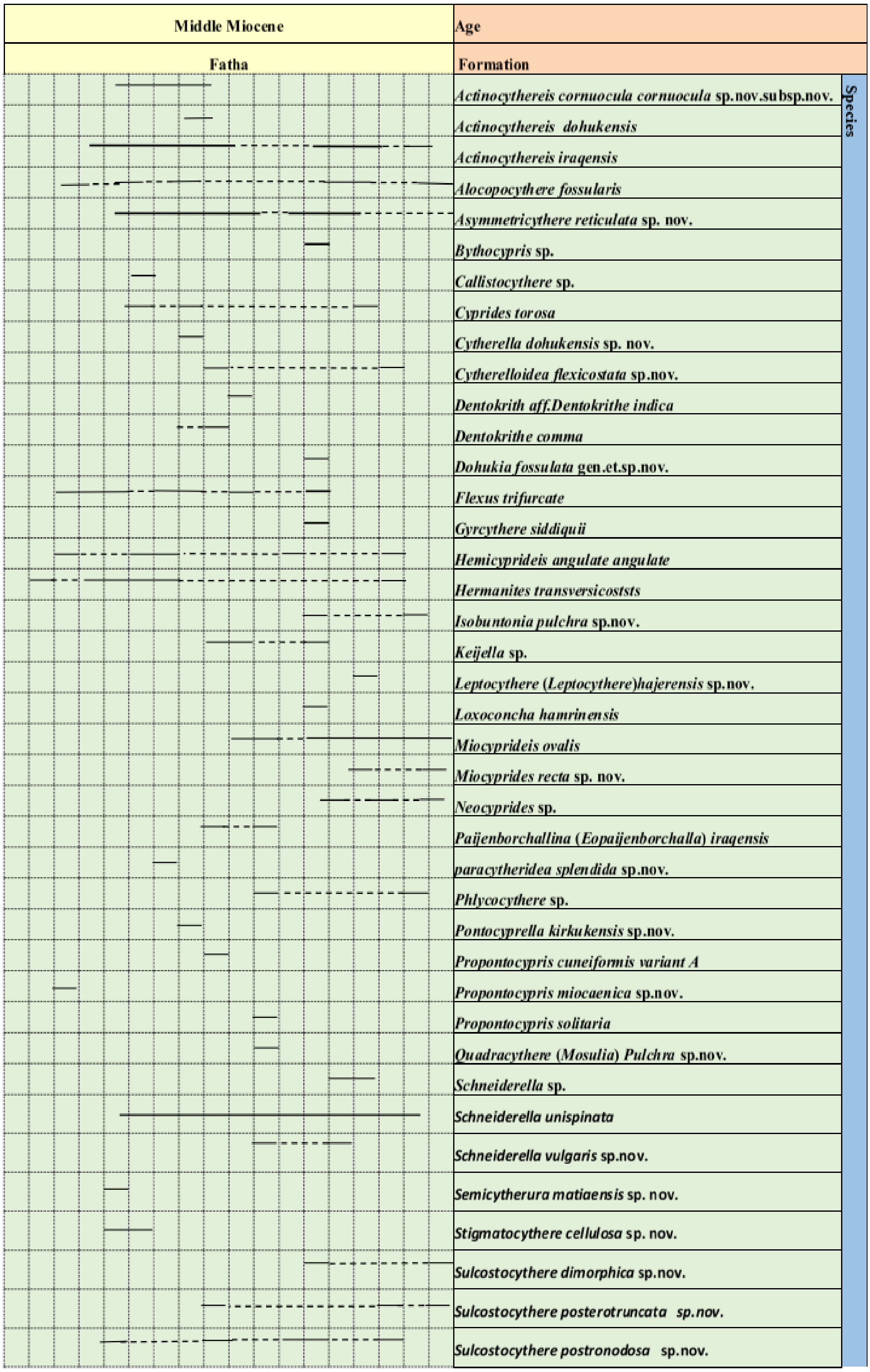


Fig. 4. Biostratigraphic occurrence of identified Ostracoda for Fatha Formation in the studied wells, Southern Iraq

Table 4. Comparing of different local biozones of foraminifera with current study

Epoch	Stage	Biozones								
		Abawi (1973)	Karim (1975)	AlMubark (1978) in Alasadi (2002)	Ahmed (1980)	Hassan (1985)	AlGeriri (1985)	Maala et al. (1988) in Alasadi (2002)	Alasadi (2002)	Present work
Miocene	Serravallian	*Ammonia beccarri Zone*	*Borlis melo cordica- Ammonia beccarri globula* Zone	*Borlis melo cordica- Ammonia beccarri* Zone	*Ammonia beccarri Zone*	*Ammonia beccarri Zone*	*Borlis melo cordica- Ammonia beccarri* Zone	*Ammonia beccarri Zone*	*Peneroplis farensis - Borlis melo* Assemblage Zone	*Elphidium craticulatum* Total Range Zone
	Langhian								*Ammonia beccarri* Range Zone	

4.4. Geological Age

There is a great deal of controversy regarding the age of the Fatha Formation, and many studies have been presented in order to determine the most appropriate age for the studied formation. The process of determining ages using planktonic foraminifera is more effective and accurate than benthonic foraminifera. Inopportunely, the current study is devoid of any planktonic genera, except one genus, therefore, the benthonic fossils were relied upon Bellen (1957) determine the *Borlis melo* is index fossil to the Middle Miocene. Also, there are several important index fossils to the lower and middle Miocene, such as *Austrotrillina howchini, Peneroplis thomasi, Nummulites fichteli, Rotalia viennoti, Miogypsina* sp.

But this study is missing these species, therefore, reliance was made on Ostracoda species to determine the Fatha Formation age, due to the high number of index fossils of Ostracoda. *Schneiderella vulgaris, Cytherella dohukensis, Miocyprideis ovalis, Miocyprideis recta, Hemicyprideis angulate, Paijenborchallina (Eopaijenborchalla) iraqensis, Dentokrithe comma, Actinocythereis iraqensis, Loxoconcha hamrinensis* etc. all the mention species are index fossils to the Middle Miocene (Khalaf, 1982; Khalaf, 1993; Khalaf, 1998; Abdol Rassul and Al-Sheikhly, 2001; Kharruffa, 2008; Al-Shumam, 2009; Hawram and Ali, 2018 and Mohammed and Al-Shareef, 2021).

5. Discussion

The current study was conducted in the Fatha Formation in the south of Iraq. Generally, the paleontological studies in Basra oilfields are rare, especially in the Fatha Formation. Most of the studies are related to formations that have petroleum accumulation. Fortunately, exploration wells were made for the Nahr Umr and West Qurna oilfields, core samples were taken for the Fatha Formation. Therefore, this study is important because it relies on confirmed depths, and those results have been strengthened and compared with cutting samples from the other oil fields. The results of the current study are different from the other, most of the foraminifera fossils are not recorded in the middle or northern Iraq, it missed the index fossils and common existence of *Elphidium craticulatum,* while this species is not recorded in other basins, it reflects the tidal environment, while the rest of the foraminiferal fossils were indicated on the lagoonal environment but this lagoon not isolated on marine water, it could be partially separated lagoon, because of the abundance of ostracods genera that reflect shallow marine environments. The salinity of the Fatha basin in the southern is less than that of the northern basins. The types of lithology and fossils emphasize that conclusion.

Table 5. Comparing of different local biozones of Ostracoda with current study

Epoch	Stage	Biozones			
		Khalaf (1984)	Hawram & Khalaf (2013)	Khalaf & Kharofa (2020)	Present work
Miocene	Serravallian Langhian	*Asymmetricythere reticulata* sp. nov. - *Miocyprideis ovali Assemblage* zone *Hermanites transversicoststs -Multilus fortireticulata* sp.nov. Assemblage zone *Cytherella sayyabi* Assemblage zone	*Loxoconcha hamrinensis* Assemblage zone *Cytherella sayyabi* Assemblage zone *Paijenborchallina (Eopaijenborchalla)* iraqensis Assemblage zone *Miocyprideis ovalis* Assemblage zone	*Cytherelloidea* sp.1 Assemblage zone *Dentokrithe indica* Assemblage zone	*Schneiderella unispinata* Assemblage zone

6. Conclusions

Forty-two species related to twenty-one genera of Foraminifera, forty Ostracoda species belonging to thirty genera were described from the Fatha Formation in the studied wells. Based on the fossil taxa found in this study, it was determined that the Fatha Formation was deposited in the lagoonal environment as the main basin but this basin is affected by tidal, subtidal and shallow marine water at the same time, especially in the lower part of the Fatha Formation, where a thin seaway connection remained open and they were in direct contact with the open sea. All genera recorded in the study area belong to benthic Foraminifera except *Globigerina quinquelob* belongs to planktonic Foraminifera.

The age of the studied formation is Middle Miocene depending on index fossils of ostracods, therefore, the current study determines one biozone for Foraminifera which is *Elphidium craticulatum* Total Range Zone. Also, one biozone for Ostracoda which is *Schneiderella unispinata* Assemblage zone, these biozones with age Langhian- Serravallian.

Acknowledgements

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References

Abawi, T.S., 1973. Miocene Foraminiferenaus N-E Iraq, N. Jb. Geol. Pal. Abh.144, 1-23.

Abdol Rassul, A.H., Al-Sheikhly, S.S., 2001. Ostracoda of Fat'ha Formation (M. Miocene), from Central Iraq. Rafidian Journal Science, 12 (4), 47-59.

Abu-Zied, R.H., Al-Dubai, T.A., Bantan, R.B., 2016. Environmental conditions of shallow waters alongside the Southern Jeddah basin on benthic Foraminifera, physicochemical parameters and heavy metals. Journal of Foraminiferal Research, 46 (2), 149-170.

Adegoke, O., Oyebamiji, A., Edet, J., Osterloff, P., Ulu, O., 2017. Cenozoic Foraminifera and Calcareous Nannofossil Biostratigraphy of the Niger delta, Elsevier publishers.

Ahmed, N.M., 1980. Facies of Fossiliferous Limestone bed of the Lower Fars Formation of some localities in North Iraq, M. Sc Thesis, University of Mosul.

Al Geriri, M. 1985. Biostratigraphy of Euphrates Formation, Northern Iraq, Unpublished M. Sc Thesis, Baghdad University.

Al-Abbasi, M.W., Sakry S.I., Karem CH.A., 2011. A study of macro fossils (Bivalvia) from Fat'ha Formation (Middle Miocene) at Shaqlawa area, Northeast of Iraq. Tikrit Journal of Pure Science, 16 (4), 1813 -1662.

Al-Asadi, M.M, 2002. Biostratigraphic and sedimentological study of Fatha Formation of S-NW of Mosul. M.Sc. Thesis, University of Basrah.

Al-Atabi, A.N.S., 2014. Determination of the oil characterization and reservoir assessment of Fatha (Lower Fars) and Ghar formations in Selected Oil Fields in South and Middle Euphrates of Iraq. Ph. D. Thesis, college of science, Baghdad University.

Al-Dubai, T.A., Abu-Zied, R.H. and Basaham, A.L., 2017. Diversity and distribution of benthic foraminifera in the Al-Kharrar Lagoon, eastern Red Sea coast, Saudi Arabia. Micropaleontology, 63 (5), 275-303.

Al-Jaberi, M., Mahdi M., 2020. Minerology and paleontology of the quaternary sediments in Karmat Ali at Basrah, Southern Iraq. Iraqi Geological Journal, 53 (2C), 105-120.

Al-Hadithi, Z.B., Aziz, N.M., 2019. Paleoecology and statistical study of Ostracoda, Fatha Formation (Middle Miocene) from Bazian Anticline, Al- Sulaymaniyah Area, Kurdistan Region, Iraq. Iraqi International Journal for Geology, 19(2), 119-135.

Al-Jubouri, A.L., McCann, T., 2008. The Middle Miocene Fatha (Lower Fars) Formation, Iraq. GeoArabia, 13 (13), 141-174.

Al-Juboury, A.I, Al-Naqib, S.Q., Al-Juboury, A.M. 2001. Sedimentology, mineralogy and depositional environments of the clastic units, Fatha Formation (Middle Miocene), south of Mosul, Iraq. Dirasat, Pure Sciences, Jordan, 28, 80-105.

Al-Kaabi, M., Hantoosh, D., Neamah, B., Almohy, H., Bahlee, Z., Mahdi, M., Abdulnaby, W., 2023. Classification of the Zubair Subzone oilfields using structural contour maps, Southern Iraq. Journal of African Earth Sciences, 197, 104770.

Al-Sharhan, A.S., Nairn, A.E.M., 1997. Sedimentary Basins and petroleum Geology of the middle East, Amsterdam:(Elsevier).

Al-Shumam, H.M., 2009. The Lower Miocene Ostracoda in well Hamrin 12 and well Ajille 6, North Iraq, Unpublished M.Sc. thesis, College of Science, University of Mosul.

Al-Shawi, Z., Mahdi, M., Mohamad, A., 2019. New records of planktonic foraminifera in the Shuaiba Formation (Aptian Age), Mesopotamian plain, South of Iraq. Iraqi Journal of Science, 60 (6), 1322-1335.

Aqrawi, A.A.M., 1993. Miocene evaporitic sequence of the southern Mesopotamian Basin. Marine and Petroleum Geology, 10(2),172-179.

Aqrawi,A. A.M. , Al-Hakim, M.K., Ashoor, S.M.A., 1989. The stratigraphic of the lower Fars Formation (Miocene) in southern Mesopotamian basin, Iraq. Journal Geological Society of Iraq, 22 (2), 25-34.

Bellen, R.C., Van, Dunnington, H.V., Wetzel, R., Morton, D.M., 1959. Lexique Stratigraphique, International. Asie, Iraq, 3c (10a), 333.

Boltovskoy, E., Wright, R. 1976. Recent Foraminifera. Junk, The Hague, 515.

Busk, H.G., Mayo, H.T., 1918. Some notes on the geology of the Persian oilfields. Institute of Petroleum Technology, 5, 321.

Christian, L. 1997. Cretaceous subsurface geology of the Middle East region. GeoArabia, 2 (3), 239 - 255.

Ditmar, V. and Iraqi – Soviet Team., 1971. Geological Conditions and hydrocarbon Prospects of the Republic of Iraq (Northern and Central Parts). Manuscript report, INOC Library, Baghdad, Iraq.

Fouad, S., 2015. Tectonic map of Iraq, scale 1: 1000 000. Iraqi Bulletin of Geology and Mining, 11(1),1-7.

Hartmann, G., Puri, H.S., 1974. Summary of Neonatological and Paleontological classification of Ostracoda, Mitt Hammdurg, 70, 7-37.

Hassan, K., 1985. Study of Foraminifera of Lower Fars in Fatha region, M.Sc. Thesis, University of Baghdad.

Hawram, O.A. and Khalaf, S.K., 2013. Ostracoda of Fatha Formation (Middle Miocene) from (Darbandikhan and Aghjalar) sections, Sulaimani- Kurdistan Region/ Northeastern Iraq. Journal of Zankoy Sulaimani- Part A (JZS-A), 15 (3), 23-46.

Hawram, O.A., Ali, H.J., 2018. New Middle Miocene Ostracodes (Crustacea) From Kurdistan Region, Northeastern Iraq. Iraqi Geological Journal, 51(2), 1-34.

Hayward, B. W., Hollis, C., Grenfell, H. R., 1997. Recent Elphidiidae (Foraminiferida) of the South-west Pacific and fossil Elphidiidae of New Zealand. Institute of Geological & Nuclear Sciences monograph, 16.

Jassim, S.Z., Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, Czech Republic.

Karim, S.A., 1975. Biostratigraphy of Red bed series (Choarta – NE Iraq). Journal Geological Society of Iraq, 47-156.

Karimina, S.M., Pessagno Jr, E.A., Carter, J., Sabeti Soraiadoost, N., 2003. Extraction of calcified radiolarian and other calcareous microfossils from micritic limestone utilizing acetic acid. Micropaleontology, 50(3), 301-30.

Khalaf, S.K., 1982. On Actinocythereis iraqensis sp. Nov. Stereo-Atlas of Osrtacoda Shells, 9 (9), 51-54.

Khalaf, S.K., 1984. Middle Miocene Ostracoda from northern Iraq. Ph.D. Thesis, University of Hull, England.

Khalaf, S.K., 1993. Some new Ostracoda species of the genera Cytherella and Cytherelloidea from the M. Miocene of North Iraq. Iraqi Geological Journal, 26(3), 175-195.

Khalaf, S.K. 1998. The Ostracdoe family loxoconchidae from the Middle Miocene of Northern Iraq. Iraqi Geological Journal, 31(1), 83-89.

Khalaf, S.K., Kharofa, L.H., 2020. Paleontological study of Ostracoda in the Fatha Formation (Middle Miocene) Hammam Al-Alil area, northern Iraq. Iraqi Bulletin of Geology and Mining, (1),1-8.

Kharruffa, L.H., 2008. Systematic Study and Stratigraphical distribution of Ostracoda in Fat'ha Formation (Middle Miocene) from selected locations; Northern Iraq, College of Science, University of Mosul.

Loeblich, A.R., Tappan, H., 1964. Thecamoebians and foraminifera. Kansas Press Lawrence, Kans.

Mahdi, A. H. I., 2007. Fossils Mollusca (Bivalve) from the Fatha Formation of northern Iraq. Iraqi Bulletin of Geology and Mining, 3(1), 41 -53.

Mahdi, M.M., Khaleefa, U.Q., Shareef, N.F., 2017. Study of Sawa lake fauna, Holocene deposits, Al-Muthanna Province, Southern Iraq. Mesopot. Journal Marine Science, 32 (2), 104 -114.

Makris, J., Henke, C.H., 1992. Pull-Apart Evolution of the Red Sea. Journal of petroleum Geology, 5, 127-134.

Manh, T., Tsukgoshi, A., 2015. First records of interstitial leptocytherids (Crustacea, Ostracoda): two new species and a redescription of Callistocythere ventricostata Ruan & Hao, 1988 collected from the Okinawa Islands, southern Japan. Zootaxa 4006 (1), 83-102.

Mohammed, M.K., Al-Shareefi, I. Y., 2021. Some records Ostracod species of genus Paijenborchellina from the Middle Miocene Fat'ha Formation, Eastern Butmah Anticline, Northwestern Mosul City, Iraq. Iraqi National Journal of Earth Science, 21 (1),1-19.

Moore, J.A., 1986. Charophytes of Great Britain and Ireland. BSBI handbook no. 5. Botanical Society of the British Isles, London.

Moore, R.C., Pitrat, G.W., 1961. Treatise on invertebrate. Paleontology, Part Q Arthropoda 3 Crustacea Ostracoda. Geol. Soc. of America and University of Kansas press, Lawrance Kansas.

Moore, R.C., 1969. Treatise on invertebrate paleontology, part N: Mollusca Geol. Soc. Am. And University of Kansas press. 6, (Bivalvia).

Morkhoven, F.P., Van, G.M., 1963. Post Paleozoic Ostracoda, part (II). Elsevier publication contributions, Amsterdam, London, New York.

Murray, J.W., 1969. Recent foraminifers from the Atlantic continental shelf of the United States. Micropaleontology, 15, 401-419.

Murray, J.W., 2006. Ecology and applications of benthic foraminifera. Cambridge University Press, Cambridge.

Rao, R.U., Rao, G.V., 1974. Results of some geothermal studies in Singhbhum Thrust Belt, India. Geothermics, 3(4), 153–161.

Schweizer, M., Nikulina, A., 2011. Molecular identification of Ammonia and Elphidium species (Foraminifera, Rotaliida) from the Kiel Fjord (SW Baltic Sea) with rDNA sequences. Helgol Marine Resource, 65, 1-10.

Sharland, P.R., Archer, R., Casey, D.M., Hall, S.H., Heward, A.P., Horbury, A.D., Simmons, M.D., 2001. Arabian Plate Sequence Stratigraphy. GeoArabia, Special Publication 2, Gulf Petrolink, Bahrain, 371.

Shurupova, Y.A., Tesakova E. M.,2021. The Ostracods (Ostracoda, Crustacea) as a Model Object for the Studying of the Evolution of Sexual Dimorphism. 4. Biology Bulletin Reviews, 11(3), 226-236.

Sissakian V.K., Al-Ansari N., Al-Kubaysi K.N., Knutsson, S., 2016. The Miocene Sequence in Iraq, a Review and Discussion, with emphasize on the Stratigraphy, Paleogeography and Economic Potential. Journal of Earth Sciences and Geotechnical Engineering, 6 (3), 271-317.

Tamar-Agha M.Y., Al-Aslami, O.J.M., 2015. Facies Depositional Environment and Cyclicity of the Fatha Formation in East Baghdad Oil Field, Iraq. Iraqi Journal of Science, 56 (4A), 2939- 2952.

Tucker, M., 1999. Sabkha cycles, stacking patterns and controls: Gachsaran (Lower Fars/Fatha) Formation, Miocene, Mesopotamian Basin, Iraq. Neues Jarhbuch Für Geologie Und Paläontologie, 214, 45-69.

Tucker, M.E., Shawkat, M.G., 1980. The Miocene Gachsaran Formation (formerly Lower Fars) of the Mesopotamia Basin, Iraq: Sabkha cycle and deposition controls. Journal Geological Society Iraq, 13 (1), 261-267.

Tunoglu, C., 2001.Pontian aged Loxoconcha (Ostracoda) species from eastern Black Sea Region of Turkey. Zootaxa, 3796 (1), 147-165.

Van Bellen, R.C., Dunnington, H.V., Wetzel, R., Morton, D., 1959. Lexique Stratigraphique International. Asie, Fase, 10a, Iraq, Paris, 333.